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ABSTRACT

The seven working papers in this collection set out the underlying philosophy and research methods of the Learning in Science Project. The project was established in 1979 to identify, describe, and investigate problems and difficulties in the teaching and learning of forms 1-4 science, and to explore possible solutions. The papers describe the frameworks established for the three phases of the project, consider strategies used to work with children both inside and outside the science classroom, and describe the workings of four action-research groups created to explore and evaluate possible solutions to some specific problems. Subject areas addressed by the action-research groups were biology, physics, chemistry, and science activities. (JN)

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LEARNING IN SCIENCE PROJECT

THE RESEARCH APPENDIX:

WORKING PAPERS ON METHODOLOGY

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THE RESEARCH APPENDIX:

Working Papers on Methodology

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EDITORS' NOTE

The Working Papers in this collection set out the underlying philosophy and research methods of the Learning in Science Project. The Project was established in 1979 to identify, describe and investigate problems and difficulties in the teaching and learning of Forms 1-4 Science, and to explore possible solutions. The papers in this collection describe the frameworks established for the three phases of the Project, consider the strategies used to work with children both inside and outside the science classroom, and describe the workings of four action-research groups created to explore and evaluate possible solutions to some specific problems. At all times, the research was directed by a concern for our work to be accepted as useful by practising teachers.

This collection has been produced in the hope that by making this over-view of the Project more readily available, fellow researchers will be able to relate our thinking and approach to the Project's findings, and use our experiences to their own advantage.

Roger Osborne

Peter Freyberg

Ross Tasker

THE WORKING PAPERS

No. 1 An initial framework

No. 14 Reconsidering the framework

No. 28 The framework: Toward Action-Research

No. 29 Towards solutions: the work of the Biology Action-Research Group

No. 32 Towards solutions: the work of the Physics Action-Research Group

No. 35 Towards solutions: the work of the Chemistry Action-Research Group

No. 46 Towards solutions: the work of the Activities Action-Research Group

PUBLISHED PAPERS AND PAPERS IN PRESS WHICH CONSIDER RESEARCH ISSUES

Freyberg, P.S. et.al., The Learning in Science Project. In Harlen, W. (Ed.) Trends in Primary Science, Paris:UNESCO, (in press).

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LEARNING IN SCIENCE PROJECT

AN INITIAL FRAMEWORK

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WORKING PAPER No 1

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AN INITIAL FRAMEWORK

A WORKING PAPER OF THE LEARNING IN SCIENCE PROJECT
Roger Osborne, Peter Freyberg and Ross Tasker
March 1979

Introduction

This paper sets down what we presently see as the major aim of the Learning in Science Project and suggests how this aim might be achieved. It attempts to take into account the various views of people who have been involved in the planning of the project up to this time.

The nature of the project

Out of the various possible aims which it has been suggested should be the focus of the project (Ralfe, 1978) the following statement seems to us to include the most important and realisable goals:

> The aim of the project is to make a study of the teaching and learning of science at the Form 1 - 4 level, to identify some of the key difficulties in this subject area, and to find ways of overcoming such difficulties.
>
> To this end three phases of evaluation and research are envisaged:
>
> (a) an exploratory phase, to observe the teaching and the learning of science in classrooms and to identify difficulties as perceived by teachers, pupils, and experienced classroom observers,
>
> (b) an in-depth phase, to focus on the teaching and learning of selected aspects of the science course e.g. topics or themes. It is expected that the selection will be based mainly on findings from the exploratory phase and that emphasis will be placed on student development of concepts, skills and attitudes relevant to selected aspects,
>
> (c) an action-research phase, based on the findings of the first two phases, to explore with teachers possible ways of overcoming the identified difficulties and problems in teaching and learning science.

The project is seen as both an evaluative and a research project in the sense that it is concerned with obtaining information for decision-making (evaluation) and yet is also concerned, particularly in the in-depth phase, with attempting to identify those factors which influence learning (research).

Exactly what is being investigated?

The project is primarily concerned with the Form 1 - 4 science curriculum. However, what is meant by the Form 1 - 4 science curriculum needs careful consideration. Let us consider this under four headings

(i) the official curriculum (official transmitted)
(ii) the teacher's curriculum (teachers' intentions)
(iii) the actual curriculum (teachers' actions)
(iv) the students' curriculum (students' received)

The official (national) curriculum is the Form 1 - 4 Science Syllabus. A revised draft syllabus was published in 1978. But the 1978 syllabus states that the 1967 syllabus "remains the approved syllabus and many teachers may elect to continue to use it as a basis for their programmes. However, all teachers are free to use the suggestions made in this draft if they consider them more helpful." Curriculum developers over the next two years aim to produce guidelines for each syllabus section from which teachers may plan classroom programmes. Six units for pupil use and teacher resources have already been written and supposedly updated for the new syllabus and are now being published. (Nevertheless, it should be pointed out that at least the first unit published has not been completely updated.) 40 - 50 small units (FORM 1 - 4) should be available as draft materials for trial schools in 1979. In summary, the official curriculum is the 1967 syllabus but modifications contained in the 1978 draft may be adopted if they are considered more helpful.

It seems likely that the teachers curriculum, i.e. what the teacher uses as the curriculum, will undergo considerable changes between 1979 and 1981 dependent upon the success of the support materials being produced by the Department of Education. A research project currently being undertaken in Scotland (Brown, 1975) is examining a similar situation in that country. The project is concerned, in part, with questions like

(i) who has taken up the new syllabus?
(ii) how are teachers implementing the new syllabus?

and is only then concerned with

(iii) what are students achieving?

The teachers' curriculum can be viewed as the teachers' intentions. With respect to this curriculum, recent changes in the official curriculum mean that an evaluative study undertaken by the project must take account of the possibly changing teachers' curriculum. Either it must address itself specifically to the problem as has been done in Scotland or it must ensure that the project is not undermined by the fluid situation.

Concern for the actual curriculum places a wider perspective on the Form 1 - 4 science curriculum than suggested above, if by actual curriculum one means everything which is deliberately organized by the teacher - the curriculum as identified by teachers' actions.' In this sense, one is not only concerned with the content of the science courses but also with the materials used by the teacher and the organization within the classroom and the school.

The variety of experiences and influences on the pupils themselves will be called the student curriculum. Not only will this curriculum include aspects of the actual curriculum but it will also include the 'hidden' curriculum - that is the variety of experiences and influences on the pupils which are not planned, nor even necessarily acknowledged, but which may nevertheless influence pupils learning, attitudes and ideas as much as the intended experiences (Snyder, 1971).

In terms of the project's aim, aspects of the 'actual' and 'student' curricula are central to the work of the project. However the relationship between the aspects of these curricula and the associated aspects of the 'official' and 'teachers' curricula will need to be explored if teachers' actions are to be related to teachers' intentions. In the exploratory phase it would seem pertinent to consider a teaching and learning event in terms of all four curricula. To ensure that the 'in-depth' and 'action-research' phases are not undermined by changing curricula in the schools it is also necessary to consider the time dependence of the relevant aspects of each of the four curricula.

Who is the audience and how are the outcomes of the project going to effect teaching?

The project's audience will be a diverse one; teachers,

teacher trainers, curriculum developers, advisers, educational researchers and so on. Each of these audiences will be interested in different aspects of the project's findings. For example:

(i) information about teachers' difficulties caused by a lack of teacher training would be of particular interest to in-service and pre-service teacher trainers;

(ii) information about difficulties of pupils in seeing the relevance of a topic or pupil difficulties caused by a lack of appropriate prior experiences would be of interest to curriculum developers;

(iii) problems arising from mismatch between pupils' and teacher perceptions of classroom happenings could be referred to advisors and in-service agencies.

However if the project is going to affect teaching and learning in classrooms then the teachers themselves should be the prime audience. Brown and McIntyre (1978) have emphasized that suggested changes must include clear explanations as to what teachers should do in the classroom. It has been observed that a teacher pragmatically will label any proposals for change as 'practical' or not. If the change is seen as practical then it may be incorporated into the teaching; if not, then it is unlikely to be tried except under coercion. It is suggested that it is not enough to recommend principles or desirable outcomes to teachers. These must be accompanied by specification of procedures. The reality is that teachers in general cannot, or will not translate for themselves the lofty aims of a changed syllabus, or other innovations, into day-to-day activities.

If the above view is accepted then a reason for the emphasis in the project on classroom teaching rather than the official curriculum can be identified. Outcomes of the project related to suggested changes in the official curriculum may have a minimal effect on teaching and learning in the classroom even if the changes are adopted by the curriculum developers. On the other hand, information on how specific classroom problems may be overcome, or information on the possible consequences of particular classroom actions, are likely to have greater impact on classroom teaching provided these have been validated in an action-research phase.

Investigations in the exploratory phase

In the exploratory phase of the project the teaching and learning of science is to be observed and the difficulties in teaching and learning as perceived by teachers, pupils and experienced classroom observers identified. In this phase of the project selected aspects of the course, e.g. topics or themes, need to be identified for in-depth analysis in the second phase of the project.

Undoubtedly the exploratory phase of the project corresponds closely to the first stage of illuminative evaluation as suggested by Parlett and Hamilton (1977). There is an emphasis at this stage in observation at the classroom level and interviewing participating teachers and students. Parlett and Hamilton (1977) suggest that the researchers should be concerned to familiarize themselves thoroughly with the day-to-day reality of the setting without focus on particular aspects. Nevertheless we consider it is desirable to have certain broad observational frameworks on which received information can be ordered and categorized. As suggested earlier these frameworks may include

(i) viewing information in terms of official, teachers, actual and hidden curricula and being sensitive to the possible fluidity of these curricula with time;

(ii) attempting to identify concepts, topics or themes* which appear central to an on-going learning, which appear or are perceived by teachers or students as difficult to teach or learn, or alternatively are well liked and well understood by pupils and/or teachers;

(iii) attempting to identify other problems and difficulties, as well as the enjoyable and worthwhile moments, which teachers and pupils experience within the institutional and national educational system in which they operate;

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* e.g. the use of models or mathematics in science teaching

(iv) being conscious of the differences in learning milieu and the differences in the students themselves between the various types of schools which teach Form 1 - 4 Science in the Waikato area (one of the reasons the project was based at Waikato is the wide variety of schools in the area);

(v) being sensitive to differences and similarities between Form 1 - 2 Science and Form 3 - 4 Science. One interesting aspect of this project is the unique opportunity of the project to cover aspects of both primary and secondary education within the framework of one study.

While emphasis has been placed here on the difficulties or concerns perceived by teachers, pupils and classroom observers it may well be desirable to canvas views of other persons as well, about what they perceive as major concerns about the teaching and learning of Form 1 - 4 Science. These persons could include

(i) the teachers who teach students who have completed the course (e.g. Form 5 teachers);

(ii) the students who have taken the course (3rd formers about Form 1 and 2, 5th formers about Form 3 and 4);

(iii) the Headmaster and Head of Science;

(iv) the curriculum officers and science advisors; and

(v) interested groups in society e.g. parents, professional industrial.

Investigations in the in-depth phase

If Form 1 - 4 science is to be studied then there are a wide variety of aspects of teaching and learning that might be considered. Some of these are listed in Table I using the category system of Frazer (1977). Within the resources of this project, limitations must be made on what is to be studied. This can be done by selecting certain aspects of Table I, by limiting the content to be studied to certain topics or themes within the Form 1 - 4 Science course, and by limiting the groups of teachers and students to be studied.

One of the functions of the exploratory phase is to provide information so that a sensible approach can be made to specifying the scope of the in-depth phase. In particular, difficulties in teaching and learning will have been identified, topics or

Table I Aspects of teaching and learning Form 1 - 4 Science that could be investigated.

These can be listed using the category system adopted by Frazer (1977).

(i) Evaluation of the Form 1 to 4 Science Syllabus philosophy
e.g. the soundness of the stated aims, the soundness of the assumptions about society's needs, the soundness of assumptions about the mental capabilities of students.

(ii) Content analysis of Form 1 to 4 Science materials
e.g. relationship of stated aims to curriculum materials, logical structure of the materials in developing concepts and knowledge, authenticity of materials, readability and quality of presentation.

(iii) Learning environment in Form 1 to 4 Science classrooms
e.g. observation and classification of classroom events, students perception of the curriculum materials and their learning environment, teachers opinion surveys about problems and strengths in using the curriculum materials, case studies in classes where the Form 1 to 4 Science prescription is being implemented.

(iv) Student outcomes in classrooms using the Form 1 to 4 syllabus
e.g. long term and short term achievements of students with respect to the objectives of the prescribed syllabus.

(v) Dissemination of Form 1 to 4 syllabus and materials
e.g. the extent to which the syllabus aims and the associated teaching materials are being implemented in different schools, with different teachers, and in different classrooms.

themes central to the teaching and learning at this (and later levels) will have been specified, and particular aspects of Table I will have been isolated for further in-depth study. Apart from this dependence on findings from the exploratory stage it must not be forgotten that the development of students concepts, skills and attitudes form the central focus to teaching and hence to this project.

Ralfe (1978) has set out possible aspects of teaching and learning which might be investigated by the project using a case study approach. These include:

(a) What do teachers claim as their objectives; how do they see themselves proceeding toward these objectives; how is this related to the official curriculum objectives and to what teachers are actually doing in science classrooms? Freyberg (1979) distinguishes between teachers' purpose, intentions, plan of action, and actions in the classroom and it is desirable to distinguish between them as implied earlier in the discussion on the various curricula.

(b) What do pupils perceive as objectives of these same science lessons; how do they think they are proceeding toward these objectives; and what are the pupils actually doing?

(c) What are the backgrounds in science of the various teachers; what are their attitudes to the teaching; what is their depth of understanding of the science content in these science lessons?

(d) What are the backgrounds in science of the pupils; what is actually being attained in the science lessons in terms of concepts, skills and attitudes; what concepts and/or process skills appear too difficult for most pupils i.e. are introduced at an inappropriate stage in their cognitive development?

Measuring the effectiveness of teaching and learning in terms of student development is a major problem in education. In this regard it may be fruitful in terms of providing useful and fresh information to teachers and curriculum developers if the project were to use, where appropriate, measuring techniques not normally available to teachers because of time constraints

and so on e.g. individual interview methods, discussion with small groups, videotape supported analysis .

It is envisaged that in this in-depth phase of the study, the research work will go beyond identifying difficulties to isolate some of the factors which have a causal relationship to the difficulties and problems in effective learning.

Undoubtedly limiting the in-depth phase to certain topics, to certain research questions, and to certain groups of teachers or students, places some limitations on the generality of the findings. We expect to find some common elements in the limited number of aspects that we are able to pursue, which will produce conclusions of wider applicability than statements related to just these aspects. The relationship between findings and audiences has been explored diagrammatically in Figure 1. Generality of the research findings is nevertheless a problem and it is one that has been of concern to researchers using the illuminative approach particularly where case studies have been used. Fensham, (1978) and Marsh et al, (1978, p.20) have suggested however that the important point is how much use the intended audience(s) can make of the information thrown up by the research findings. If generality is redefined in these terms, they suggest case studies and other illuminative approaches may well be of greater 'generality' than broad based psychometric studies.

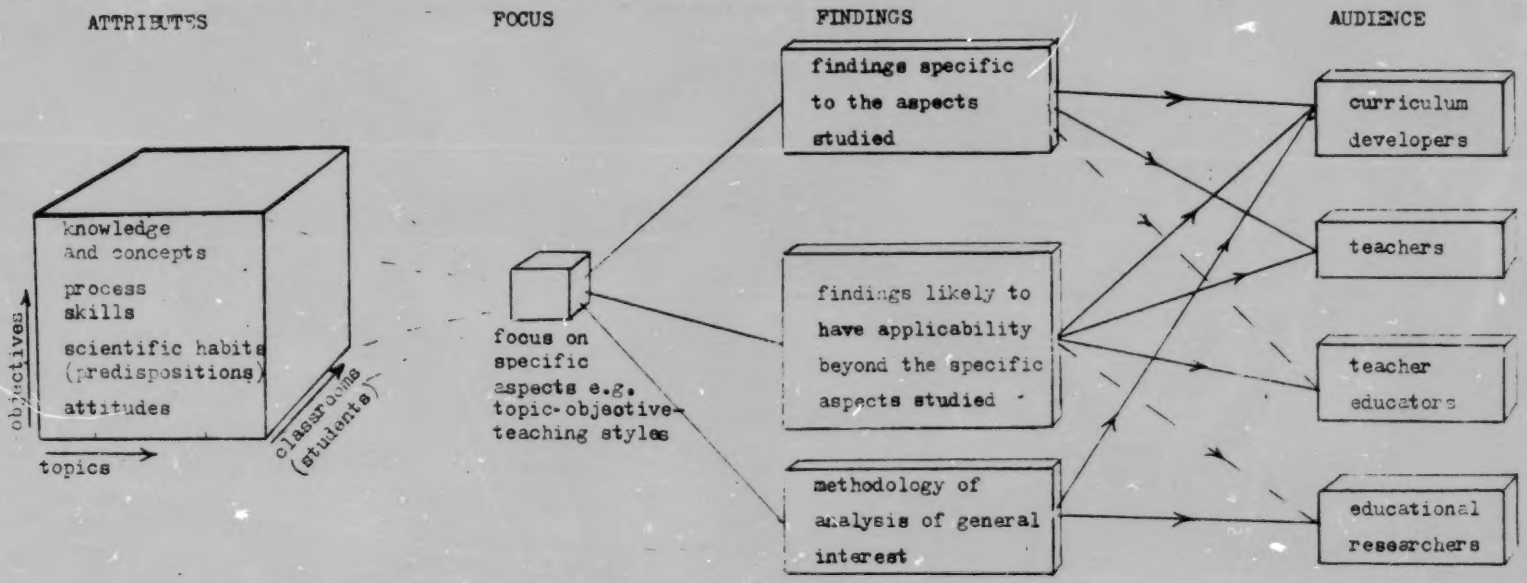
The project's advisory committee has suggested that with respect to providing information useful to teachers the findings of the project will need to set out the conditions under which certain outcomes are likely - teachers could then fit themselves into the situation (to the extent they considered appropriate) and use the information accordingly.

The action research phase

As the action-research phase is to be based on the findings of the first two stages the actual form this phase will take cannot be defined at this stage. However, what is clear is that in terms of this action-research phase of the project, the teachers are the crux to success. From this point of view the focus must be on issues that are seen by teachers to be important or issues which teachers can be convinced are important. Successful action-research necessitates awareness of the problems and the solutions

Figure 1 Focus on specific aspects of Form 1- 4 level Science

- not to the mutual exclusion of other aspects but rather an emphasis on specific topics, themes or objectives.



Criteria for choice of a specific aspect of Form 1-4 level Science, e.g. a topic

(i) topics which are perceived as difficult or a problem by teachers, pupils, or observers

(ii) topics which include central basic scientific concepts which will be built on later

(iii) topics which include a wide variety of process skills, scientific habits and attitudes

amongst the teachers who are actually doing the teaching. Harlen (1978), for example, has argued that a style of evaluation that involves teachers in deciding what information to gather, and how to gather it, and in discussing criteria for evaluating it, is more likely to benefit not only the individual schools but the system as a whole.

In this phase not only must ways be devised and tested for overcoming the difficulties uncovered in the earlier phases of the project but the effectiveness of the proposals must be critically evaluated.

Other considerations and constraints

Ethical considerations

Any research must be just and beneficial to all concerned i.e. the teachers, the pupils, the Department of Education, and others interested in the curriculum. Any evaluation makes the greatest demands on teachers, who quite naturally value their autonomy and privacy and are likely to find certain kinds of intervention or exposure threatening. It is important to realize, for instance, that teachers are likely to fear any evaluation which they consider might

(i) destroy in some way the personal relationship they have with students ;

(ii) possibly expose an incompetence of which they are unaware ; or

(iii) criticize them in unreasonable or subjective ways.

Teachers can also be concerned that their professional status will be undermined if they allow someone to comment critically on their work. These factors must be taken into account and may place constraints on the research work that can be undertaken in practice. The need to negotiate the clearance of information offered by participants and used as data in the research before distribution to anyone else, has been commented on by Simons, (1977).

Time considerations

The project is to run for two and one-half years and to ensure completion of the project in terms of a satisfactory end point, at least a tentative overall plan of action or time-table is required. Table II is an attempt to produce such a

Table II Timetable Plan for the Learning in Science Project

		EXPLORATORY PHASE	IN-DEPTH PHASE	ACTION-RESEARCH PHASE
1979	M	planning of the phase, goals and methods.*		
	A	familiarisation with the classroom	survey and design of possible measurement and observational instruments	
	M		trial of instruments	
	J	observer, teacher and pupils opinions canvassed and analysed		
	J		OVERALL METHODOLOGY CLARIFIED, TOPICS OR THEMES CHOSEN.*	
	A			
	S			
	O	further familiarisation but with respect to chosen classroom topics and teachers for the in-depth phase	training of observers, critical examination of topics or themes chosen, refining instruments to chosen topics, preliminary data collection	
	N			
	D		FINALISE DETAILS OF METHOD FOR THIS PHASE	survey and tentative design of this phase
1980	J		observation and measurement in the classroom with respect to specific themes or topics	
	F			
	M			
	A			
	M			development of this phase and trial of methods *
	J			
	J			
	A			
	S			
	O			
	N			FINALISE DETAILS FOR THIS PHASE
	D			
	J			work with teachers and in classrooms
	F			
	M			
	A			
	M			
1981	J			finalise write up
	J			REPORTS
	A			

* selection of schools, teachers and/or observers for the phase being considered

timetable. The details encompassed by the shaded boxes identify important points in the project planning.

Summary

The Learning in Science Project is particularly concerned with difficulties in teaching and learning Form 1 - 4 science. To investigate these difficulties a three phase project has been planned. The project is not seen simply as an evaluation exercise which is prescriptive and based on authority, nor will it involve large scale testing, nor evaluate either the syllabus or teaching. Rather it is seen as a research project concerned about finding ways of overcoming difficulties in the teaching and learning of science at the Form 1 - 4 level through small-scale in-depth studies. It is seen as something which can only be done collaboratively with teachers, and it is aimed at providing outcomes easily related to classroom decisions.

Teachers are often cynical about educational research and this cynicism is often justified in the sense that most research findings either confirm information that teachers knew all along or result in propositions so esoteric that they are seen to be of little relevance to classroom practice. Our task is to provide fresh and valuable information of relevance to informed decision making.

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LEARNING IN SCIENCE PROJECT

RECONSIDERING THE FRAMEWORK

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WORKING PAPER No. 14

RECONSIDERING THE FRAMEWORK

A WORKING PAPER OF THE LEARNING IN SCIENCE PROJECT

Roger Osborne, Peter Freyberg, Ross Tasker, Keith Stead

April 1980

Introduction

The first working paper of the Learning in Science Project, "An initial framework", produced in March 1979, outlined what was then seen as the major aims of the Learning in Science Project and suggested how these aims might be achieved. One of the major decisions made at that time was to envisage the Project as involving three phases of research: an exploratory phase to observe the teaching and learning of Form 1 - 4 Science in classrooms and to identify difficulties as perceived by a variety of people; an in-depth phase to focus on the teaching and learning of selected aspects of science at this level, and an action-research phase based on the findings of the first two phases.

Now, at the commencement of the in-depth phase, it seems desirable to reconsider the initial framework, to re-affirm or modify the decisions made a year ago and to specify more clearly at this stage in the project our plans for the in-depth phase and its relationship to the proposed action research.

We wish to say at the outset that our reconsideration of what has been achieved in the initial phase of the project has confirmed our views on the basic philosophy, the broad goals, and the methods which we initially envisaged for the project. In particular we would wish to reaffirm the emphasis of the project on (i) the 'actual' and 'student' curriculum, (ii) the learner as the initial focus of study and (iii) the need for the project outcomes to be of relevance and use to the classroom teacher.

The exploratory phase

Investigations during the exploratory phase followed closely both the intention and the timetable as detailed in the initial framework. As outlined by Tasker et al (1980) much of the data collected in the exploratory phase came from recorded interviews, and observations, of teachers and pupils. Additional information was also gathered in recorded interviews with others associated with Form 1-4 Science, namely inspectors, science advisers, ex-pupils and so on. A major concern was to maintain high context validity and to this end considerable attention was given to the way interviews were set

up and access to the classroom gained. It is envisaged that, in the final stages of the project, papers outlining the strategies adopted to gain access to classrooms, and also to gain information in classrooms and in interviews with pupils, will be produced both for other researchers and for teachers. In retrospect an important aspect of the exploratory phase was the establishment of a colleague relationship between members of the project team and teachers in the area. This provided teachers with the confidence to readily invite us into their classrooms and to allow us to work freely with their pupils. All interviews and classroom proceedings were recorded on audiotape, transcribed and then each transcript searched for possible significant statements. These key statements were annotated on the transcript and categories of information established and the specific issues ordered within these categories. New categories emerged whenever a comment or observation could not be placed in an existing category. Early transcription and categorization of the material acquired was found to be essential, since it was then possible to explore issues as the data gathering proceeded and thereby isolate idiosyncratic comment from that of wider concern.

Relatively quickly the need to generate new categories was diminished and gradually comments, and associated observations in classrooms tended to support views already expressed or perceived rather than to add a fresh perspective. Figure 1 details the categories grouped under national issues, local issues, and classroom issues related to teaching and learning. Most of the teaching and learning categories were further divided into three components;[1] comments related to teaching by teachers, pupils, and others; comments related to learning by these same groups of people; and thirdly specific examples of the problems and difficulties which had been commented on, as recorded by our own classroom observers. Attempts to isolate particular problems and difficulties from the categorized data were soon abandoned as a great many specific problems and difficulties were found to be interrelated. Eventually, eleven broad aspects of Form 1-4 Science which seemed to usefully organize the information available, emerged as meaningful foci. These foci and the stronger link each had to the various categories established are indicated in Figure 1.

Comments and observations relating to these various foci were collated in a set of discussion papers, known as the FOCUS Papers (Working Papers 2-12).[2]

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[1] Denoted by a (3) after the category name

[2] These Papers, along with Working Papers No. 1 and 13, form Freyberg et al (1979

As well as serving to describe problems and difficulties in Form 1-4 Science the focus papers were written in a way which it was hoped would open up the problem issues to a wider audience than those involved in the project team. A selection of readers was asked to feedback to the project their thoughts about the focus issues in terms of a number of specific questions. In this way the papers were seen as a way to test the validity of our findings and a way of involving the audience of the project's ultimate outcomes in decision making relating to the in-depth phase of the project. In practice it has been found necessary to actively seek out comment from individuals and groups of people, rather than to rely on spontaneous feedback.

Up to the present time most comments that have been received tend to elaborate issues rather than raise new aspects or challenge statements made. There has been no really contradictory comment and in general readers have tended to be supportive, agreeing that the issues raised are the issues they also see as valid and important. In the light of these comments, and from our own thinking on these issues together with the guidance of our advisory committee, decisions have been made in relation to the in-depth phase of the project.

The in-depth phase

In the 'initial framework' it was stated "the in-depth phase will focus on the teaching and learning of selected aspects of the science course. It is expected that selection will be based mainly on the findings of the exploratory phase and that emphasis will be placed on student development of concepts, skills and attitudes relevant to selected aspects."

In the exploratory phase a wide variety of issues related to Form 1-4 Science have been explored. Many of the issues raised were not seen as appropriate or profitable for further investigation within the Learning in Science Project. For example the resolution of some issues require extensive comparative surveys for which we do not have the resources. Increasingly it has become clear to us that the project could best concentrate on the problems of learning science and then, and from that perspective, approach the problems of teaching science. The focus papers, EXPERIMENTS, LEARNER, KNOWLEDGE, PROCESS SKILLS and ATTITUDES in particular, focus on issues which are seen as of central concern to the Learning in Science Project. Our readers reaction to these papers have reinforced our view that the learner should be our first concern.

As to our initial intention to place emphasis on the development of student knowledge skills and attitudes relative to selected aspects of teaching and learning science, the work of the exploratory phase has not only enabled us to gauge the importance of these issues but also to clarify more clearly three identifiable and related aspects of Form 1-4 Science in which they are imbedded. These three aspects which we will label CHILDREN'S SCIENCE, CHILDREN'S CLASSROOM

EXPERIENCES and CHILDREN'S OUTLOOK ON SCIENCE provide the three distinct but related investigatory probes of the in-depth phase (Figure 2). Each of these aspects of the in-depth phase will be considered in turn.

Children's science

Science is concerned with how and why things behave as they do. However scientific knowledge involves not only ideas about such events, but also a meaningful language whereby these ideas may be communicated to others. From our work in the exploratory phase of the Project it is clear to us that children do acquire some sort of coherent view of the world based on their experiences, but not surprisingly these views are not necessarily consistent with those of the scientist. Also, children do have meanings for many words used in science, but again those meanings may be quite different from those of scientists using the word in a scientific way. For example, an animal is for many children a four-footed mammal, whereas the scientist uses the term with much wider reference. By children's science we mean the views of the world and the meanings for words that children do have and bring with them to science lessons. We would argue that the more we know about children's views and language the more we will be able to provide learning experiences for them as pupils whereby their ideas can be modified and developed; so that they can interpret events and words from a more scientific perspective or, where this is beyond them, at least appreciate aspects of the scientific perspective.

If one aspect of the in-depth phase is to investigate children's science then we have to consider how this might be done. In an earlier working paper (No. 3) the interview about instances method (I.A.I.) [Osborne and Gilbert, 1979] was used to investigate students meanings for the word 'force'. We have now developed a second but similar, type of interview, called interview-about-events (I.A.E.) which is used to explore various aspects of students' views of the world. In this latter type of interview, a particular set of events, e.g. water boiling, condensing, ice melting and so on are demonstrated to the interviewee. The child is asked to describe what (s)he sees happening and then asked to explain, in his or her view, what has happened. Having gained insight into the child's view of the event, the interviewer then investigates what knowledge the child has of the scientist's view and how this relates to the child's ideas. As detailed in Figure 3, both I.A.I. and I.A.E. can therefore be considered to involve three phases, and both can be extended to a fourth phase which explores in terms of the background of the particular interview, the child's outlook in science. To illustrate the I.A.E. method, the set of events used in a study of physical change are given in Figure 4. In Appendix I extracts from interviews exemplify the type of information which can be obtained in the final two phases of such an interview.

It is now necessary to consider what aspects of children's science should

be considered in the in-depth phase. If children's science and scientist's science are concerned about things and about how and why they behave as they do, then it would seem sensible that science teaching for most of the school population should first be concerned about the familiar world in which the child works and lives. One might categorize both children's science and scientists' science into three areas:

(a) things that cause other things to happen, for example "why do I slip when I walk on icy surfaces?"

(b) things that sometimes turn into other things, for example "why do shiny nails sometimes turn into rusty nails?"

(c) things that live and die, for example "what are spiders and where and how do they live?"

From the work of the exploratory phase, from the collating of comments from a variety of people on particular concepts and topics, from meetings with specialist and interested groups to focus down on particular concept areas, and finally, with consideration of the extent and nature of the manpower available to the Learning in Science Project, a series of investigations has been planned for the in-depth phase. The words, and events to be investigated, the insights into children's science which it is hoped might be evoked, and the particular aspects of scientists' science which are related to these studies are detailed in Figure 5.[3]

A variety of outcomes of this work on children's science is envisaged. Firstly, with respect to particular science topics a clearer appreciation of children's language and views of the world should be established. In terms of the action research phase of the project such knowledge will provide a firm basis on which to design teaching strategies which will not only challenge individual pupil viewpoints but will provide experiences whereby these viewpoints can be replaced or modified.

Secondly we have already observed aspects of children's science which are common to a wide variety of concepts and viewpoints. Children have egocentric and anthropocentric views; they tend to resort to anthropomorphism and animism; they tend to dismiss things they cannot observe as not existing, they tend to reify some abstract ideas, e.g. force, momentum, and there is confusion between the specialist and everyday meanings for many words. In addition, as students gain an understanding of the scientists' view of the world they sometimes get basic scientific concepts confused, e.g. confuse electrical energy and electric

[3] It is anticipated that younger children will have little or no understanding of the scientists' view while for some older children the distinction between their views and the scientists' views will be indistinguishable.

current, they gain superficial knowledge with little or no real underlying understanding, and they acquire and retain in their knowledge store quite contradictory views, [Osborne and Gilbert, 1980]. Such generalized findings across concepts may well help us to suggest types of lessons which may overcome some of the blocks which seem to prevent children from reaching a more scientifically-coherent viewpoint.

Children's Classroom Experiences

The classroom is but one of many areas of experience that contribute to the various views of the world 11-14 year olds hold. Nevertheless, in terms of helping to shape particular aspects of these views it can be a powerful influence. The classroom provides a series of 'episodes' (teaching and learning opportunities) orchestrated by the teacher. In Form 1-4 science classrooms such episodes often take the form of investigations or experiments which are variously intended to involve pupils in activities requiring the use of scientific processes and habits; to lead pupils to outcomes of scientific significance; and to foster in pupils an interest in science in general.

Our work in the exploratory phase raised questions regarding the effectiveness, as a teaching and learning mechanism, of investigations and experiments (tasks) as currently practised in Form 1-4 science lessons. Of particular concern was comment and observations which frequently suggested a lack of correspondence between expected pupil outcomes, as indicated by teachers' and/or textbook writer's intentions for specific tasks, and actual pupil outcomes, achieved as a result of watching or carrying out such tasks. With so much teaching and learning of science at this level being centred on investigative and experimental tasks it became apparent that these classroom experiences required further study.

Of major importance is the strong contextual influences on most classroom tasks. Realisation of this led us to the decision that in-depth studies must be carried out in the natural setting i.e., in normally operating Form 1-4 science classrooms and lessons. The work is taking the form of a series of observations each supported, as appropriate, by gentle questioning. The observations are aimed at establishing four aspects in relation to any episode: what the actual task is; what the pupils actually do; what outcomes the pupils actually achieve; and what the significance of actual pupil outcomes are in terms of 'view of science' (i.e., pupils' science, teachers' science and scientists' science) and scientific skills and habits. The questions attempt to establish both pupil and teacher perceptions in respect of the above four aspects. The relationship of observations to both pupil and teacher perceptions is set out in Figure 6.

Teacher and pupil actions observed are recorded in notes made at the time of observation, while an audio-record of verbal interactions (teacher-class, teacher-pupil, pupil-pupil, pupil-observer and teacher-observer) is made on audio-tape. Other methods (video-taping and polaroid photography) for noting observations have been considered but concern over disruptive effects on normal class proceedings has so far excluded their use.

As soon as is possible after observation of an episode, the audio-recording is transcribed and annotated, as required, from the notes made during the observation (Figure 7 contains extracts from an annotated transcript to illustrate the type of record obtained). The annotated transcript is then searched for, actions and comments of possible significance, and identifiable issues are then categorized in the manner used in the exploratory phase of the project (see p 2). The process of analysis, confirmatory search, and re-analysis is regarded as complete when all further observations of key events and statements can be fitted into existing categories, rather than requiring the establishment of new categories, and also by the clarity of descriptions of the categories themselves.

At this stage of the work only the nature of the outcomes rather than the actual outcomes which will develop out of the described analysis are predictable. It is envisaged that intensive study of science classroom episodes will provide insights into the nature and extent of mis-matching of pupil actions, perceptions and outcomes, with teacher intentions and perceptions. In addition, it is hoped, that those task characteristics which influence pupil outcomes will be identified and that the nature of such influence can be described - for example, the nature and role of links between specific process skills and scientific habits and the outcomes which pupils achieve. Such information, when obtained, will provide the basis for the Action-research phase of the Project, as well as being of direct interest to science developers and science teachers.

Children's outlook on science

An important aspect of any science course is children's outlook on their science studies. This relates not only to children's motivation and enjoyment but also to their desire to pursue the study of science beyond the fourth form. Our observations and literature search in the exploratory phase of the project have identified two general areas of concern. First, there are considerable differences in the numbers of girls and boys who continue their study of science subjects (particularly the physical sciences) beyond the fourth form. Secondly, it has been observed that the majority of Maori and Polynesian students soon turn away from science. The differences in outlook on science of these groups, and the associated affective, linguistic, cultural and sociological influences which may be causing them, is providing the focus of study for the third and final area being investigated in the in-depth phase of the Project.

It is our present view that one of the important aspects of our work in this area is to learn, appreciate, understand and accept, the different value systems, expectations, thinking styles, learning preferences, perceptions and beliefs of the particular groups of learners identified above. The girls, or Maori students, who "fail" in science could have done so for a variety of reasons, of which lack of ability is only one. They could, for example, have rejected the academic criteria for 'success' long ago, not so much as being irrelevant but being simply non-relevant. The pupils who come from a background in which the learner is expected to rely primarily on his/her own eyes and not to question the instructor is disadvantaged when this particular role is denied them and they are expected to ask questions of their teachers in order to learn. The learners who are 'person' oriented rather than 'thing' oriented may well dislike science because it is perceived as lacking in social involvement. The pupils who habitually ascribe their academic success or failure as being completely beyond their control present a different kind of motivational problem to that of the students who take complete responsibility for their own progress. Similarly pupils who prefer to project their own organization on to the material presented to them may well feel restricted by demands to think in a prescribed way. They may prefer to respond affectively rather than analytically. Perceived scientific knowledge and methods of science may conflict with traditional beliefs or religious teachings and present the learners with a difficult decision with respect to retaining or rejecting family belief systems.

Furthermore, certain groups of students have particular problems with language in relation to science. Reference has already been made to the difficulties which arise when everyday words are used in the scientific sense. However, this kind of difficulty is increased for those pupils with a restricted vocabulary (as a consequence of it being part of a second language or of limited verbal experiences). Problems that arise include the free interchange of such words as the logical connectives "if" and "when"; the lack of familiarity with every day roots from Greek or Latin which enter into scientific vocabulary ("geo", "therm", "ante", "anti", and so on); a complete absence in the learner's language of necessary concepts (e.g. infinity, hypothesis) and particularly for some Island groups interference from non-decimal counting systems and the confusion of tenses and plurals.

In the in-depth phase of the project, therefore, work on children's outlook on science will attempt to explore the types of issues raised above, and, in so doing, will attempt to identify the nature, extent and relative importance of some of the variety of factors which influence the learner's affective response to his or her science. The exploratory phase revealed something of the range and complexity of the tangle of attitudinal and motivational factors involved (see Focus on Attitudes). To explore the development of particular value systems,

learning preferences, beliefs and expectations a systematic interviewing schedule across a fairly wide range of pupils, teachers and parents is being employed.[5] The interview approach also provides the flexibility to enable the interviewer to explore in depth the expressible reasons why learners and small groups of learners profess to like or dislike aspects of science. However it is also felt desirable to try and gain insight into the deeper, often implicit and often unrecognised, reasons for particular attitudes. For this reason attempts are being made to complement the interview work by information gained using a variety of alternative techniques. The potential of such techniques as the Repertory Grid (Fransella and Bannister, 1977) and various paper and pencil instruments are being explored at present.

The Action-research phase

This phase of the Learning in Science Project will be concerned with developing teaching strategies which build on the knowledge gained in the in-depth phase. Some indication of the kinds of contributions each in-depth aspect can make to this phase has already been given. However, in addition to establishing specific areas in Form 1-4 Science that can usefully become the focus of action-research, each will provide other valuable information. 'Children's science' will suggest directions for challenging specific viewpoints of children in ways which enhance the likelihood of the scientific viewpoint becoming established and integrated into pupils' cognitive structures or at least appreciated. 'Children's classroom experiences' and 'children's outlook on science' will suggest new practices likely to enhance modification of pupils concepts, skills and attitudes. These new practices may require a reconsideration of the relationship between learner and task as well as of learning objectives.

The jumping off point in our development of new curriculum strategies will be first to attempt to teach individual children whose views we have previously explored. Hopefully, some generally successful teaching strategies will be sorted out, which can then be tested with small groups of children before modification, development and appraisal in the classroom setting. In the final stage a range of teachers and classes will be involved.

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[5] As the cross-cultural differences in attitude and motivation are recognized as providing particular problems for the learning and teaching of science, several schools and communities with high Maori and Polynesian populations are involved in this work.

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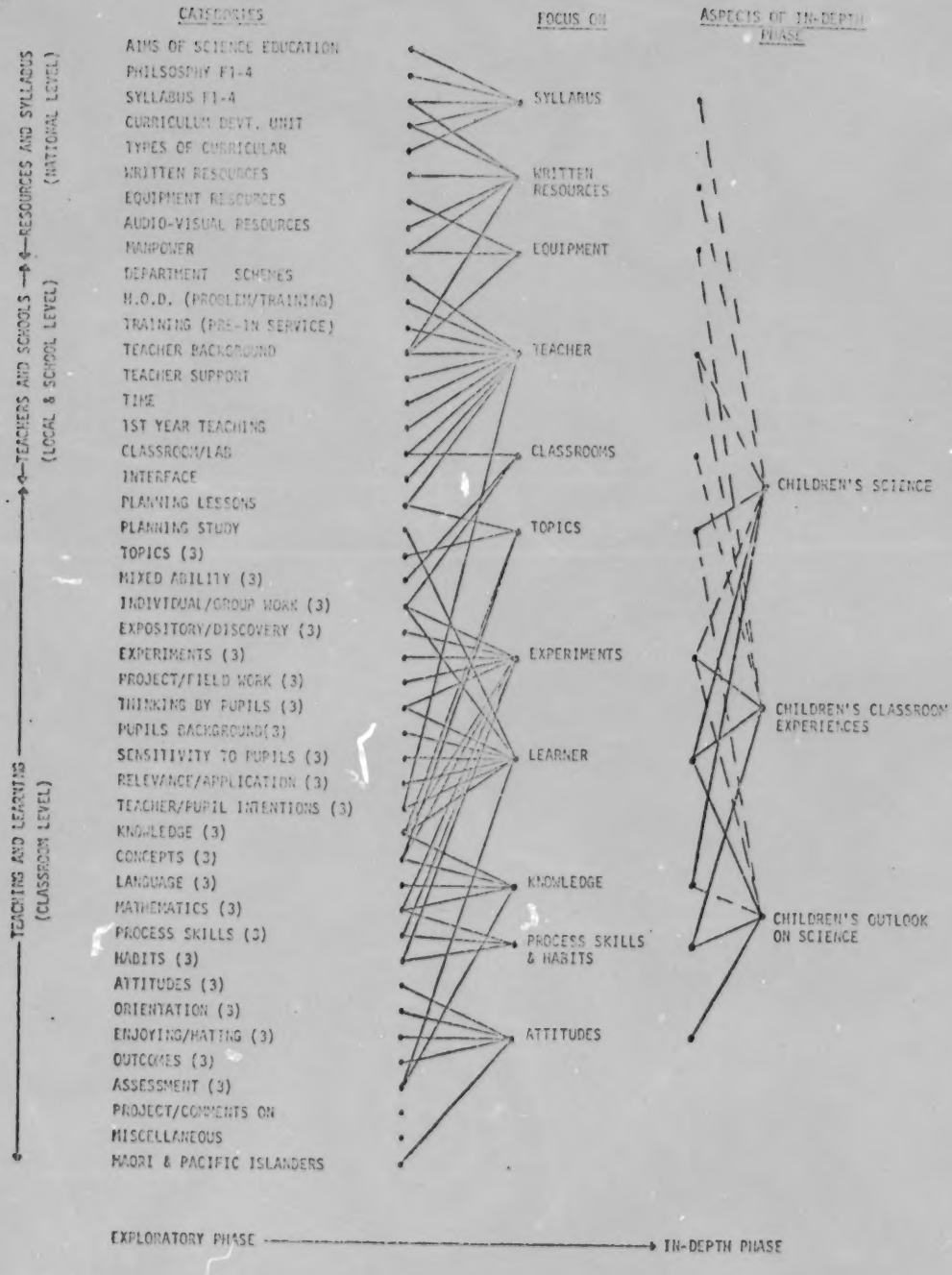
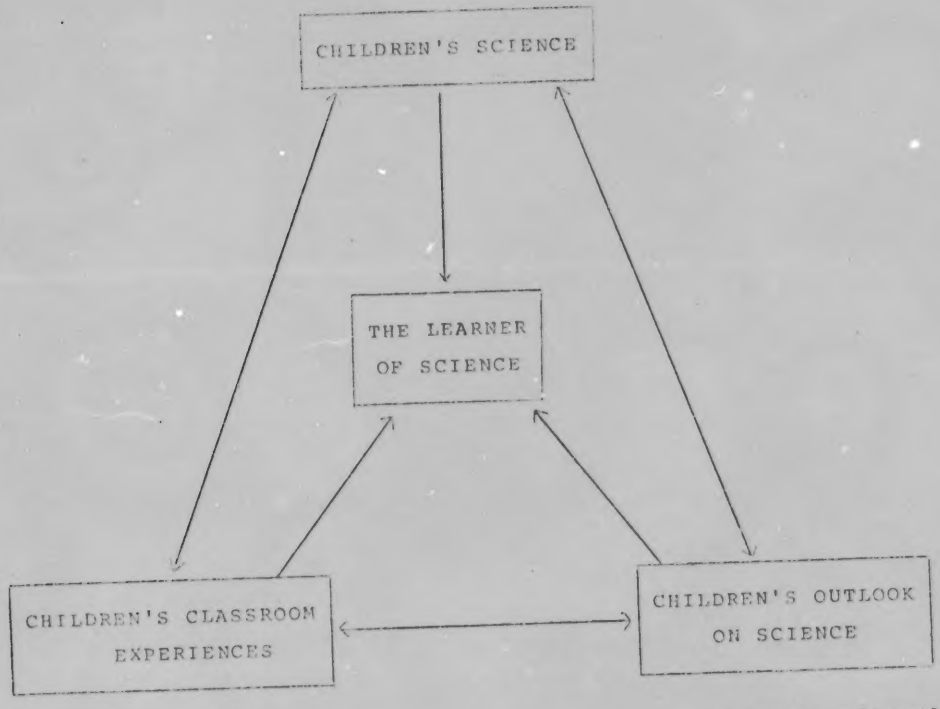


Figure 1: Categories and foci of the exploratory phase and the relationship of these to aspects of the in-depth phase.

probing children's minds in terms of their views of the world, and their meanings for the words they use.



probing children's experiences in the science classroom, particularly where children are doing science.

probing children's outlook on science, particularly the influence of various factors, e.g. affective, linguistic, cultural and sociological, on this outlook.

Figure 2: The three aspects of the in-depth phase of the learning in science project.

PHASE I AND II - gaining the child's meaning for a word (I.A.I.) or a child's description of a particular event (I.A.E.).

⇩

gaining some insight into aspects of the child's model of *how* and *why* things behave as they do.

⇩

PHASE III - gaining some insight into the child's understanding of the scientists' language and view of the world.

⇩

PHASE IV - gaining some insight into the child's outlook on science and on learning science.

Figure 3: Both I.A.I. and I.A.E. can be considered a three, or even four, phase process.

Interview schedule

1. Water boiling in an electric jug.
2. Steam from the jug condensing on a plate.
3. Sugar dissolving in a cup of warm water.
4. Water evaporating from a warm plate.
5. Water condensing on the outside of a jar containing ice.
6. Ice melting.

Typical Questions e.g. on boiling

(i) where do the bubbles come from?
(ii) what are the bubbles made of?
(iii) where do the bubbles go to?
(iv) what is the steam made of?
(v) what is the water made of?

Figure 4: Exploring the child's view of physical change using the Interview-about-Events technique.

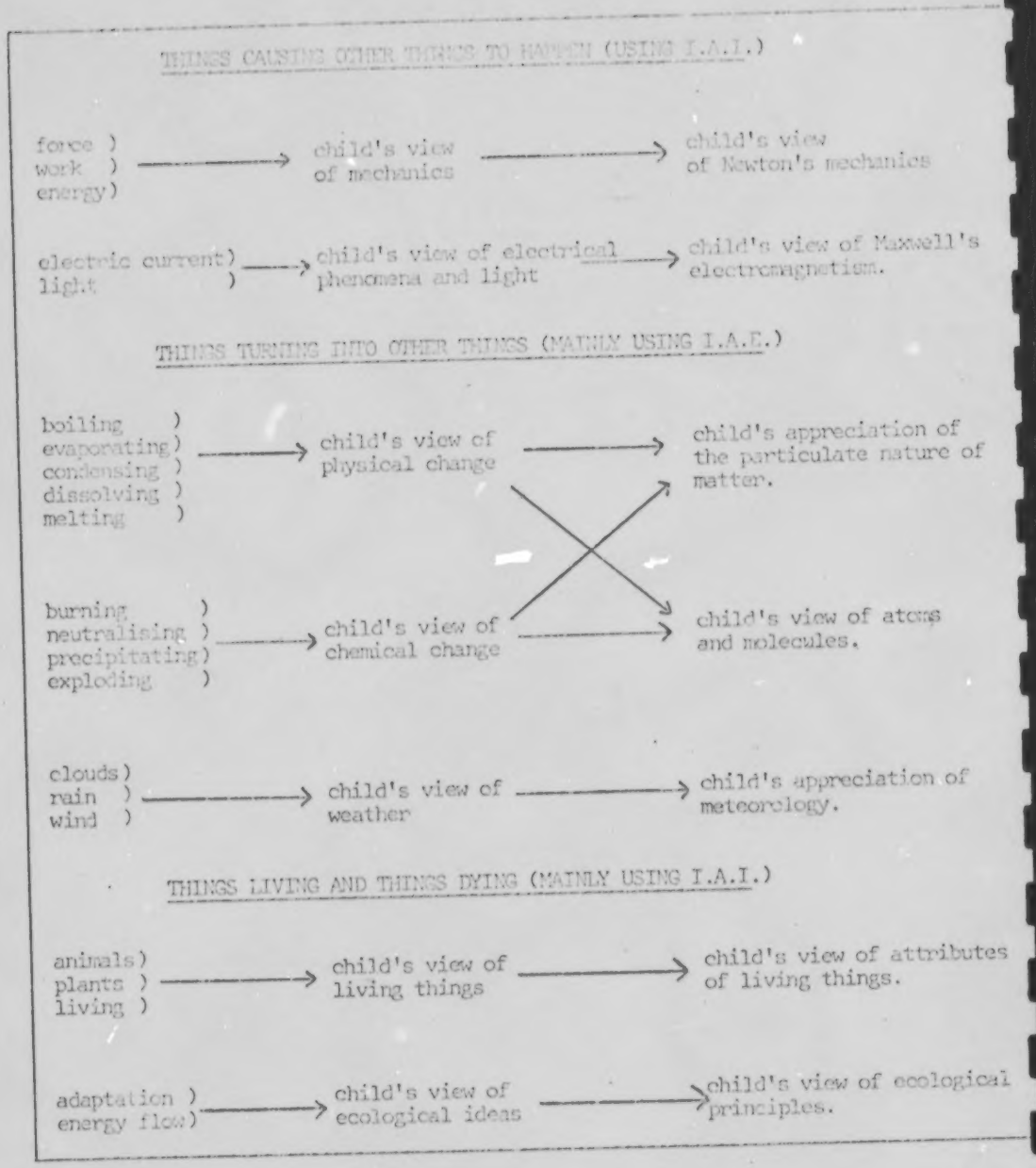


Figure 5: Aspects of science under investigation in the in-depth phase.

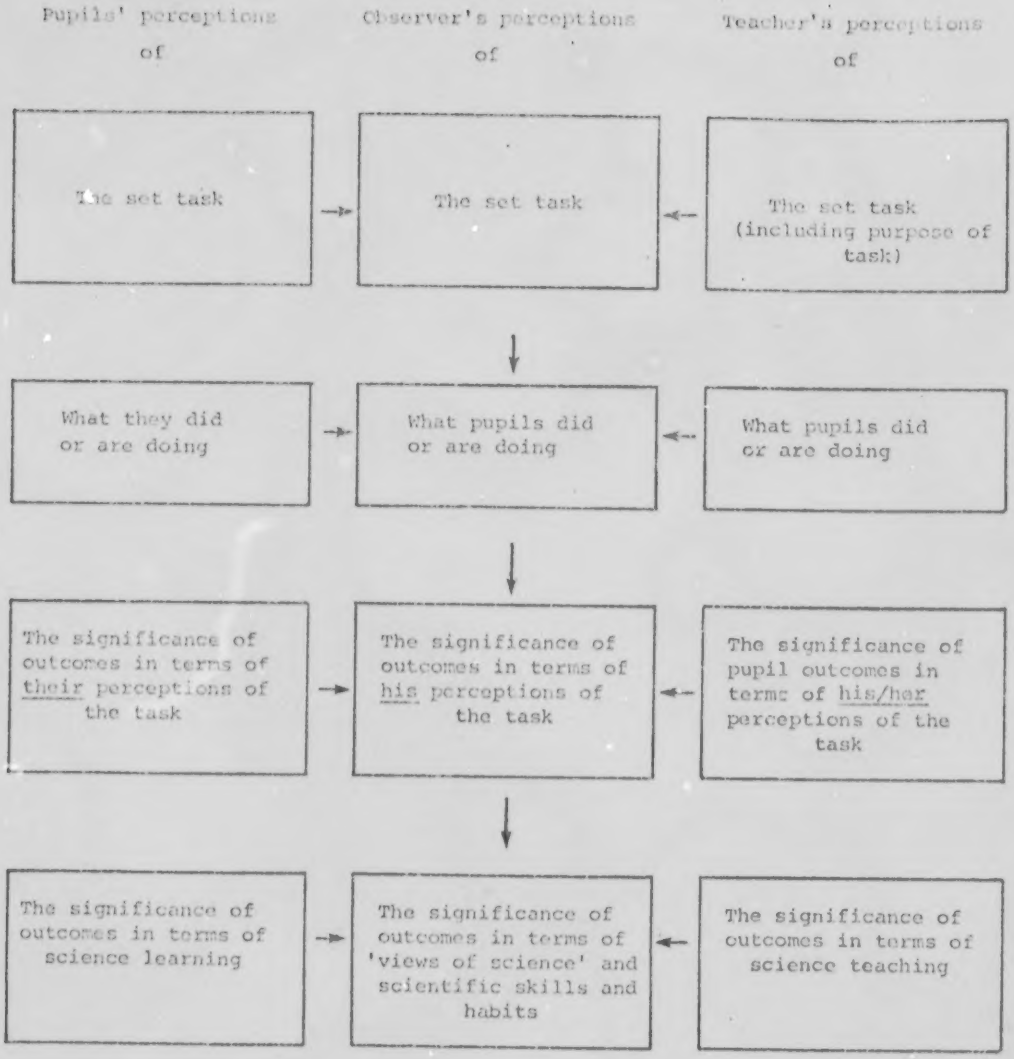

Pupils' perceptions of
Observer's perceptions of
Teacher's perceptions of
The set task
The set task
The set task (including purpose of task)
What they did or are doing
What pupils did or are doing
What pupils did or are doing
The significance of outcomes in terms of their perceptions of the task
The significance of outcomes in terms of his perceptions of the task
The significance of pupil outcomes in terms of his/her perceptions of the task
The significance of outcomes in terms of science learning
The significance of outcomes in terms of 'views of science' and scientific skills and habits
The significance of outcomes in terms of science teaching

Figure 6: Observing science classrooms.

The following conversation comes from a group of boys in a class of 13 year olds. They were instructed to half-fill three test-tubes - one with sugar solution, another with a starch solution and the third with water. To each of these was to be added a few drops of Benedict's solution (blue-green in colour) using an eye-dropper. Finally each solution was to be heated gently and any changes noted.

The observations [in brackets] are from notes made as they carried out the task.

P1 Did you wash it out?

P2 Yeah, I washed these [test-tubes].

P1 Did you wash the dropper?

P2 Yeah, I will.

P1 Shall I change this [test-tube] because it's got little bits of iodine in it? [P2 had not washed away completely the materials used in the previous task].

P3 It'll be all right.

P2 This is the sugar [adding Benedict's solution to the sugar solution by immersing the eye-dropper in the sugar solution, then squeezing the bulb].

P1 Can I hold it [over the bunsen flame]?

P3 If you turn it on its side it heats up quicker - get the flame like that [tilting the test-tube and lowering it to sit just above the top of the bunsen barrel].

P1 We don't want the glass melting [shifting the test-tube up into the hottest part of the flame!].

P2 Hey, it's going - look at the colour.

P1 Yellow.

[P2 adds Benedict's solution to the test-tube containing the starch. He uses the same eye-dropper without rinsing it and the same 'immersion' technique, then holds the test-tube in the bunsen flame].

P2 It's gone a light green.

P1 A yellow-green colour.

[P2 repeats the procedure in exactly the same way with the water sample].

P2 What colour? Yellow ... It's kind of orange.

P3 They're all the same now.

[At this point the teacher interrupts the class - she states that people must be getting their solutions mixed up because groups she has observed are getting the wrong results. She tells them to repeat the work].

P3 Why are our tests all wrong? We didn't get ours mixed up.

P2 That's what she said.

P3 I bet you they were right.

P1 I dunno what we did wrong.

Figure 7: Part of an annotated transcript obtained from observation in the classroom.

DEAN'S VIEW OF PHYSICAL CHANGE HAVE BEEN EXPLORED USING THE INTERVIEW-ABOUT-EVENTS DETAILED IN TABLE 2. HE HAS THE IDEA THAT AIR AND WATER CONSIST MAINLY OF OXYGEN AND HYDROGEN AND THAT WATER CHANGES INTO AIR ON EVAPORATION. THE FOLLOWING IS AN EXTRACT FROM PHASE III OF THE INTERVIEW.

I. In written work on chemical equations and things, have you written H_2O? (Yes) Now what does that mean to you? Does that fit into anything we have been talking about this morning?

D. Yes, well the H is hydrogen ... it is a symbol ... splitting up the substance of air into the main things ... the hydrogen which is your H and the oxygen which is your O.

I. And what is the $_2$, does that (the 2) mean anything to you?

D. The H_2 ... well if I hadn't been taught Science or Chemistry, I wouldn't be able to have a clue but from what I have been taught ... I might be wrong, but the way I have seen it, and the teachers have been trying to teach me ... that is the two is representing say that the hydrogen always goes around in two parts but it has got to have both parts to be called hydrogen ...(and the oxygen?) It exists as sort of one whole thing ... but whatever the hydrogen is made up of (it)is sort of split into two different sections.

I. O.K. what about other things like nitrogen?

D. That's by itself too.

I. Have you ever heard of Carbon dioxide? (Yes) How would you write that?

D. CO ... now hold on ... yes ... CO_2.

I. CO_2 now the 2 there does that mean anything to you?

D. Um, the only thing I could say ... I wouldn't say oxygen is split into two things ... you still have your carbon acting as an individual ... and the oxygen acting as an individual but because they have been put together you get this little 2 which is sort of a mixture of both carbon and oxygen ... that is like the linking up ... here is carbon ... here is oxygen (points to the air) and when you bang them together you get CO_2 because the 2 is sort of the thing that keeps them together.

LATER THE INTERVIEWER HAS FINISHED THE FIRST THREE PHASES OF THE INTERVIEW. SOME VERY CONFUSED IDEAS ABOUT CHEMISTRY HAVE BEEN UNEARTHED. THE FOLLOWING EXTRACT IS FROM THE FOURTH AND FINAL PHASE OF THE INTERVIEW.

I. Did you do much Chemistry in the 3rd and 4th form?

P. We did quite a bit ... we did quite a bit of writing chemical equations ... it took me ages to pick it up as I found it quite confusing ... as I know from lots of people, that at my age it is ... but after a while I started to understand it ... how to write some things ... and how some things got like that ... but (having been) taught be a teacher one way (I tend to) relate it in the same way but in my own words and my own thinking ... in an exam I would probably get it wrong but I could still think of it that way ... ... (You see,) when we are told to swot for a test we have got to swot in our book all the stuff the teacher's way ... we go home and we (try to) learn that, but as soon as it hits our eyes it goes in our brain (and) it goes the other way ... and (so) when we come to write it down and we think ... and write it down all our way - because of course it still means the same thing, there is no difference - but to the teacher there is a distinct difference between our way and (the teacher's) way ... and (the teacher's) way is the right way ... that's what I find hard ... ... if I could say how a teacher could instruct the class I would say he teaches the theory his way and says right ... and gets every kid in the class to write down their way of seeing that ... not what he has written but their way and puts it all together and tries to get a happy compromise and if there is absolutely no comparison try something else ... if there is then try and work on the kids' way ... and use the kids' ideas but every so often relate it back to his way ... just so they can see the relationship ... that's how I would like to see it done.

Appendix I: The type of information obtained from the last two phases of an interview-about-events.

LEARNING IN SCIENCE PROJECT

THE FRAMEWORK:

TOWARD ACTION RESEARCH

University of Waikato
Hamilton, N.Z.

WORKING PAPER No. 28

The Framework: toward action research

A working paper of the Learning in Science Project

Roger Osborne*

February 1981

INTRODUCTION

Two previous working papers of the Learning in Science Project "An initial framework" and "Reconsidering the framework" recorded the thinking of the Project team at the outset of the exploratory, and the in-depth, phases of the project, respectively. This paper briefly reconsiders the work done in the in-depth phase and then discusses some central issues, and tentative ideas, at the point in time when the project moves into the third and final phase: the action-research phase.

THE IN-DEPTH PHASE

The Children's Science aspect of the work carried out in the in-depth phase of the project concentrated on finding out about children's meanings for words and children's views of the world with respect to a variety of topics. The terms and views investigated, and the working papers associated with the findings of each investigation, are listed in Table I. In general this work followed the pattern outlined in Working Paper No. 14 "Reconsidering the framework" although it was decided

(i) with regard to Physics topics to follow our study of FORCE, with associated studies of FRICTION and GRAVITY rather than consider the topic of WORK;

(ii) with regard to Chemistry topics to study children's ideas of PHYSICAL CHANGE, and CHEMICAL CHANGE as well as separately to study their ideas about PARTICLES; and

(iii) with regard to Biological topics to study PLANTS, ANIMALS and LIVING in some depth, and to replace the study of adaptation and energy flow with a study of ENERGY without restricting this to a biological context.

*see acknowledgements

These investigations of Children's Science were extensive, involving some eight full-time and part-time researchers and some 500 individual student interviews. It soon became clear to us that because of the general interest in this work, and the valuable information we were acquiring from it, our intended move from the in-depth to the action-research phase of the project in August 1980 needed reconsideration. While some action- research work, on ANIMALS, was begun in Term II 1980, action-research on FORCE, FRICTION and GRAVITY was rescheduled for Term I 1981.

Action-research on the Chemistry topics was rescheduled to begin in Term II 1981. This sliding change from in-depth to action-research allowed time for both discussion and organisation, as well as being appropriate in terms of the increased man-power available[1]. Further, work of the in-depth phase of the Project raised some central educational issues which required consideration and these will be discussed later in this paper.

With regard to the work on Children's Classroom Experiences a methodology for the analysis of the experiences gained by children in the classroom setting was developed (Tasker, 1980). In addition, ways of portraying lessons which are useful both to the class teacher, and to others beyond the classroom, have been established (Tasker and Osborne, 1980). The task of extracting issues from the complex web of the many analysed lessons will be continued during 1981. One aspect of this work, the teaching of specific experimental skills, will form one aspect of the action-research phase of the project. However it is also expected that continued analysis of classroom lessons will provide valuable information to feed into the action-research evolving from the Working Papers 15-26 on aspects of children's science.

With regard to Children's Outlook on Science, the in-depth phase of the project will continue during most of 1981 as individual students are studied in considerable depth. It is also expected however that this work will contribute to some aspects of the action-research mentioned above by providing valuable information for instructional design.

1 Mr Brendan Schollum, a chemistry teacher joined the Project in January 1981 for a year as a Visiting Teaching Fellow of the University of Waikato.

In Table II, the timetable for the Learning in Science Project with regard to the in-depth and action-research phases, and the interdependence of the various phases of our work, is outlined.

TOWARD ACTION RESEARCH

Our work in the in-depth phase of the project has demonstrated to us that children, even prior to entering intermediate school, often do have clear-cut views of the world and meanings for many words used in science lessons. Often these views and meanings are considerably different from the consensus view of scientists. Rather than being based on 400 years of intellectual endeavour, they are often pragmatic and self evident views based on, and largely compatible with, everday experience.

It is also clear to us from our studies that children's views of specific phenomena and meanings for particular words (see Working Papers No 15-26), as well as their tendency to view things in particular ways, e.g. egocentric and human-centred viewpoints, animistic viewpoint, reliance on the senses and so on, can be tenaciously held despite considerable exposure to science lessons.

In our view the nature, the prevalence and the resistance to change, of children's non-scientific views, are not fully appreciated either by teachers or by curriculum developers. We ourselves have been surprised, even intrigued, by the viewpoints children hold with respect to the words and views we have talked to them about. Moreover these children's views tend to be not just idiosyncratic, and where we are able to compare our findings with similar overseas studies we find New Zealand children are not alone in the views that they hold.

If teachers are unaware of the conceptions that pupils bring to their classes, and proceed to provide experiences based on an assumed background, it is perhaps not surprising that children's views frequently remain uninfluenced by classroom experiences, or that they are modified in unanticipated ways. Our work supports Ausubel's suggestion that instruction which ignores the conceptions which pupils bring with them

rather than taking them into account, is likely to make children's scientific misconceptions more elaborate and stable instead of extinguishing them (Ausubel et.al., 1978)[2].

If the above contentions are accepted then they raise some central questions, both in terms of strategies for teaching science and for the aims of science education itself. To explore these issues it is first necessary to consider aspects of both the content of science, and the processes of science, and their relationships to science teaching.

PROBLEMS RELATED TO THE CONTENT AND PROCESSES OF SCIENCE

Layton (1973) points out that science as an area of study has developed dramatically in a very short period particularly when compared with the total development of mankind: the major advances have taken place in the last 250 years compared with some 100,000 years. He suggests that

> "A necessary, although by no means sufficient, requirement for this remarkable surge of intellectual activity was the introduction into scientific thought of conceptions of which there were no directly observable instances ..... the ideas of linear inertial motion ..... the doctrine of atoms ..... By the use of theoretical entities, or constructs, which were not obviously derived from an everyday view of the world, but which were creative products of the scientific imagination, the explanatory and predictive powers of science were progressively increased..... The use of highly abstract concepts which are connected to experimental observations by complex logical relationships, in conjunction with the close liaison of experimental science and mathematics, has enabled science to achieve intellectual advances of unprecedented magnitude." (p168)

Layton goes on to suggest, however, that the very steps which have increased the power of science as a mode of intellectual enquiry has "generated formidable problems associated with its teaching". We have to deal with the abstract nature of the subject. Also the tendency of science to concentrate upon relatively simple phenomena and idealizations,

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2 Other possible interactions that may occur between children's conceptions and teaching are explored further in Freyberg and Osborne, 1980 and Gilbert, Osborne and Fensham, 1981.

e.g. frictionless trolleys and perfect reflectors of light,to the exclusion of much of the complexity and imperfection which characterize real life problems, leads to a detachment of the subject from everyday experiences. Hence although scientific knowledge may be useful to society through the development of applied science and applications, one might question if such knowledge is directly useful to the "man in the street".

In an attempt to encourage students to view things from a scientific perspective, there has been a tendency during the last two decades to bias the objectives of science teaching toward learning about the procedures of science and developing scientific knowledge using a discovery approach. Layton(1973) considers a basic flaw in this approach is the assumption it incorporates; that science is an activity that simply requires commonsense and that appropriate "skills" are the primary ingredients of doing productive work. There seems to be, he contends, no explicit recognition of the powerful role of the conceptual frames of reference within which scientists, and children, operate and to which they are firmly bound.[3] Also Layton considers that there are problems in expecting that a discovery approach ... where it is hoped pupils will get to think about scientific ideas in the systematic way that scientists do .... will enable the procedures of science to be learnt. First the adoption of a discovery approach in the teaching of science is not logically prerequisite to children obtaining an understanding of scientific procedures. Moreover on the basis of even the most superficial analysis of the nature of scientific activity, it seems clear that discovery methods will not necessarily enable children to think and work in ways characteristic of a successful practitioner of science.

With regard to this last point Layton suggests developments in science do not necessarily develop either from the induction of a theory[4] from experimental observations or simply by the refutation of a

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3 Layton's views here relate closely to comments about science and scientists made by Einstein, see Appendix. Einstein's views on scientists and science apply equally, we would suggest, to children and learning science.

4 Here the word theory is used in a narrow sense - an hypothesis, a tentative explanation, idea or model. It is not being used in the sense of an established scientific theory e.g. theory of evolution.

theory by an experiment - any theory, even at odds with certain experimental facts, is better than no theory. Rather developments often occur from a three cornered fight between two theories and an experiment. It follows from these ideas that if we seriously want children to gain anything other than the most naive and unsophisticated understanding of the procedures by which scientific knowledge grows and changes, then children should be placed in a position where they need to consider two alternative explanations, which they or others might have suggested, and the experimental evidence which determines their scientific fate. Alternatively they need their explanations confronted by experimental evidence which will lead them to develop alternative explanations. These must then be evaluated against their original explanation.

IMPLICATIONS FOR THE TEACHING OF SCIENCE

Let us now reconsider some of the ideas presented so far

(a) Children hold plenty of ideas and theories about how and why things behave as they do - ideas which can, within limitations, be logical and coherent. These ideas can be tenaciously held and may be modified in unexpected ways as the result of teaching.[5]

(b) Accepted scientific concepts are often rather abstract and do not follow readily from children's everyday experience nor do they always relate easily to that experience.

(c) Scientists, and children, are bound by their conceptual frames of reference and science frequently proceeds by the comparision of two explanations with an experimental result rather than the simple refuting of an explanation by an experimental result; inadequate explanations remain unless replaced by more adequate explanations.

How do these propositions impinge on how and what we teach? The first statement above, (a), suggests that learning must be considered more a process of modifying or changing existing ideas rather than just the

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5 This is likely to be particularly so if children views are not identified prior to instruction

filling of blank minds. The second (b) suggests that we have to accept that it may not be possible, or even desirable to attempt, to modify all children's ideas toward a scientific perspective. The third (c), suggests we might teach scientific ideas more effectively, and at the same time give children better appreciation of the nature of science, if we were to design learning experiences for children in such a way that children's predictions based on their ideas are compared, by them, with predictions based on the alternative ideas of others. Only <u>then</u> are experiments undertaken to test the opposing ideas (see for example Nussbaum and Novick, 1980).

Are these three suggestions mutually compatible with the situation in mixed ability classes? Let us explore further the idea that it may not be possible, or even desirable, to modify all children's ideas toward a scientific perspective. Van Aalst(1980) states

> "If we accept that common sense knowledge is pragmatic and self evident, we see how it contrasts with the system of science teaching whereby we try to stimulate pupils to set problems, to think about explanations and to create alternative explanations .... I think that for many pupils the gap between this type of school science teaching and common sense knowledge is too big. Adolescents seek social acceptance: there is an inceasing age clannishness. If an individual wishes to be accepted by his equals he must abide by their standards, or he will be an outsider. I think this puts serious limitations on school science teaching and especially on the development of scientific thinking. In an informal classroom environment common-sense thinking plays a role. A classroom environment that accepts common-sense ideas on the one hand and stimulates cognitive development in the direction given by scientific reasoning on the other constitutes one of the major challenges we face." (p413)

Some children undoubtedly have the capability, and are ready to understand and to appreciate abstract scientific ideas. They can compare and contrast their own ideas with a scientific view, they can accept that a particular scientific view is more powerful and satisfactory than their own view, and can accept the scientific view as their own. With such children lies the advancement of our scientific and technological culture. However we must accept that for some, even many children, it may

well be that in terms of their everyday lives there is little to be gained by their attempting to understand a scientific framework, e.g. Newtonion dynamics. If we can bring these pupils to an awareness that there is another framework which scientists find useful, but which they may not wish to accept as their own personal view, then we may have achieved as much as we would wish for these children. Finally for some children, all we might be able to expect in terms of this aspect of teaching science is that they acquire some new experiences about the ways in which things behave. Questions as to "how and why" may be neither of interest to them nor within their capabilities to grasp.

MODIFYING CHILDREN'S VIEWPOINTS

The ideas discussed in the preceding section lead to some very basic questions about what the aims of science teaching should be and how these aims might be most effectively achieved. Accepting for the present that we wish to encourage the development of a scientific perspective at least for some children - which particular children we may not be able to identify immediately - let us consider how this might be achieved.

Perhaps the most widely reported accounts of attempts to modify children's viewpoints has been those by Geory Delacote and others in France. Tiberghien (1980), for example, considers that we must accept that children have particular views; we must value these views and explore them; we must evoke from pupils, and, <u>if necessary</u>, offer,[6] alternative viewpoints; and we must encourage pupils to test opposing ideas experimentally.

Tiberghien (1980) spends a considerable proportion of her paper discussing a learning situation made available to a pupil, Marie-Noelle. While Marie-Noelle's experiences successfully changed her viewpoint toward a more scientific perspective, the same learning situation used with a second child was not successful. In discussing this work Tiberghien comes to the view that for successful teaching the child must be sufficiently motivated and have an adequate intellectual development to be able to ask <u>herself</u> questions and to restate questions asked in <u>her</u> terms. Then,

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6 Our emphasis and interpretation of Tiberghien.

"In order to answer these (her own) questions, the teaching sessions gave Marie-Noelle the opportunity to carry out the experiments, to discuss with other children and with the teacher and to consider relevant information given by the teacher. The experiments (she carried out) were the occasion of a confrontation between her opinion (invalidated by the experiment) and the opinion of the teacher or another child (conferred by the experiment). This stage seemed to us to be fundamental, the tension experienced by Marie-Noelle had allowed her to develop and reorganise her thoughts. This presupposes teaching conditions which supply the opportunity for this confrontation. This necessitates that through the teaching, the child recognises an alternative explanation to her own. The teaching must therefore clearly give the necessary information, by experiments, explanations by the teacher, by discussions, by reference books, etc. The personality of the teacher must allow him to accept the tension which is created, that is to say, allow the child to explain herself and to retain her point of view, without correcting her. The teacher must also be able to help the child to overcome these tensions.

It also assumes that the child must be capable of coping with the confrontation. This presupposes that she can make explicit her own interpretations (if they exist) and that she can retain them in order that they be confronted with others." (p 299)

Tiberghien concludes by suggesting two clearly necessary conditions for such learning:

(i) It is important that the child takes over the initiative to ask himself or herself questions about the interpretation of phenomena presented in lessons.

(ii) It is important that the child makes his or her personal interpretation and confronts that, along with alternatives proposed by others, with experimental findings.

What can be said in favour of the approach?

(a) It views teaching in terms of an operation which attempts to start with the child's view and to end with a modified child's view. The child's original ideas can be considered and valued. They can be

related to the views of peers and to the views that scientists held in the past[7] and hold now.

(b) The approach views the learning process in a similar way to Layton's view of scientific advancement; children, like scientists, will not change their view, or explanation simply by its being reputed with regard to one situation. They must first perceive a better view or explanation to replace the presently held view.

(c) The approach accepts the belief that sometimes children have to be offered an alternative viewpoint. Many scientific ideas are so contrary to intuition that children are almost certainly not going to think of them by themselves, e.g. the idea of atoms.

The approach outlined above is not new. However, it possibly gives a greater prominence to children's initial ideas than we have often given them in the past. It suggests, in our opinion, that it is necessary, prior to a teaching episode for teachers to have been made aware, through curriculum support material, of the types of views children hold, as well as of the scientific viewpoint expressed in children's language. This we believe will give the teacher confidence to cope with a situation in which a variety of viewpoints will undoubtedly be brought forward (if permitted) to be discussed and analysed. At present in our experience, many teachers restrict discussion and dogmatically state the scientific viewpoint often in sophisticated scientific language. These teachers are unsure where a free discussion will lead and feel unprepared to cope with the unanticipated ideas which children may bring forward. Curriculum materials must provide valid information about other teachers past experiences in adopting this approach. Here then is the need for action-research; to attempt trial lessons and to provide accounts of what occurs in such lessons. This might well include:

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7 Many children's views are similar to views held by scientists in the past. Aristotle had the views he did, not because he was a concrete thinker in Piagetian terms but simply because he did not have 400 years of scientific knowledge and understanding on which to build.

(i) Full details of the common responses made by children to particular teacher questions.

(ii) Information about how teachers handled particular questions from pupils.

(iii) Teacher and pupils comments on what they thought about the lesson.

If the aim of science teaching, for at least some children, is to encourage them to adopt a scientific perspective, is the above all that is necessary in the teaching of science? Undoubtedly it is not. Scientists have many conventions; they define concepts in ways useful to them but which conflict with commonsense experience and usage. These differences between defined scientific concepts and everyday concepts associated with the same label need to be made explicit using a wide variety of carefully chosen instances and non-instances in discussion. This may not involve experimental work at all[8]. Similarly other conventions, - for example, conventions scientists have adopted with regard to graphs and diagrammatic representations - must be gradually and carefully introduced. An excellent example of how this might be done with regard to electrical circuit symbolism is given by Durey (1980).

Also as Layton (1973) points out, one of the problems with children testing out ideas of their own, and of others, about how and why things behave as they do is that it "leads to an emphasis on viewing science as an inevitable progression to even greater degrees of abstraction and purity. It can lead to an emphasis on the stereotype of the pure scientist supremely oblivious to the applications and wider implications of his or her work. Science is studied as an end in itself". Many of the children who are capable of gaining a scientific perspective may not become scientists but they may move into applied fields. Their interest is in applications. Teachers, supported by curriculum materials, should show pupils how scientific ideas and models enable us to make sense of a

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8 It could involve discussion groups using the cards we have used in our interview work followed by class discussion which includes teacher explanation of why scientists have adopted the definition they have.

wide variety of everyday phenomena, and show pupils how specific scientific ideas have been applied in technology and industry. Later, at more advanced levels, we need to help pupils take a natural phenomenon or piece of technology and identify several features using their acquired scientific concepts (Fensham, 1980). If pupils can be placed in a position where they are able to recognise the efficacy of scientific ideas and where they can see the power of these ideas to make sense of the world then, we believe, the pupil's grizzle that "science is not relevant"[9] must surely fade.

SCIENCE FOR ALL

While the above ideas may be pertinent for those who are interested and capable of appreciating aspects of the scientist's view of the world, it seems reasonable as Van Aalst (1980) suggests that for some children this type of pure science is not for them. For example Tiberghien (1980), Drury (1980) and others in France place considerable emphasis on children verbalising their views and discussing them. Some children have few formulated ideas about how and why things behave as they do - what is, just is. To others, while they may have a view or a theory it is a rule for action and they are unable to verbalise it[10].

In almost all New Zealand situations at the Form 1-4 level we have to accept that we will have both able and less able children in the same class. How can we challenge and interest children of all abilities at the same time? Two possible solutions are proposed for discussion. Either we teach in the way outlined previously for capable students while at the same time ensuring that there are manageable and achieveable goals for the less able or we change the priorities of science teaching. We will discuss these two ideas in turn.

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9 When students say science is not relevant they can mean "not related to the way I think about how and why things behave as they do" or "not related to the natural or technological world" or both.

10 As anyone who has solved a manipulative puzzle knows, it is possible to be able to solve the puzzle before you can really explain <u>how</u> you do it.

(a) From science to technology

The methods of teaching outlined earlier with respect to the more able pupils may not be incompatible, in junior science teaching, with the teaching of those who are not ready to, do not wish to, or are unable to, modify their viewpoints. For some our goal may be simply to get them to appreciate that there are other views different from their own; that scientists are a group of people with a consensus view different from theirs but one that is found to be useful for some purposes. For others, the proposed method of teaching may simply provide opportunity for children to observe carefully and record data, to explore how things behave without being concerned at all with why they behave as they do. Whatever level of scientific thinking individual children are capable of we would wish to move at some stage, and sooner for the less able, from scientific ideas related to the topic to technological or applied science applications of the idea. It has become clear to us that we as teachers and curriculum developers must provide those essential links between scientific ideas and their application[11].

What does this mean in terms of how we might design a particular lesson? Let us consider this in the context of a classroom investigation where we wish to encourage children to develop ideas about water (vapour) in the air. As starting point we might ask children (age 11-13?) to watch a warm dinner plate covered in water slowly become dry.[12]

(a) We could ask pupils to predict what will happen and to formally record this. (individually 5 minutes)

(b) We would definitely want children to watch carefully and record in as much detail as possible what they saw happen.
(in pairs 10 minutes)

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11 For the less able the technological applications would not be supported by a full scientific understanding but it may be unrealistic to expect that they should.

12 One of the important aspects of this would be the need to introduce the topic in such a way that pupils see the situation as a worthwhile one to investigate. The problem the teacher has chosen for the pupils needs to become the pupil's problem.

(c) We would wish to encourage children to express their views about what they think has happened and why. We might need to guide them to ask "Where has the water gone to?" and to think about that question. (in groups of 4 or 5, 10 minutes)

(d) We would want pupils to discuss the variety of views put forward and, if it hasn't already been brought in, the teacher might introduce another view (the scientific perspective) but in a similar language to that of the children's views.
(class discussion, 10 minutes)

(e) Pupils might be encouraged to devise experiments to test out some of the different ideas proposed e.g. "the water has gone into the plate", "the water is in the air but in such small droplets that you can't see it", "the water has changed into air".
(some groups of able pupils, 1/2 a day!)

(f) Other pupils could be encouraged to investigate whether the plate dries faster if it is hot or cold, in the sun or the shade, or in a wind or no wind.

(g) Childrens' findings, whether of an abstract nature (from (e)) or of a more applied nature (from (f)), would then be related to as wide a variety of everyday examples and associated phenomena as possible.

It is suggested that the pupil records, in their books, might contain things like

(i) what we observed;
(ii) what we thought (possibly a variety of views);
(iii) what scientists now think about this.

and so on. For young children, and for less able older children, our teaching aim might be to achieve (a) and (b), and hence (i) only. For older, and more able, children we may be able to proceed to (c) and

(d)[13], and hence (ii), and even (iii). For others we might proceed to (f) directly, excluding (c) to (e). Where ever possible, and for a wide an ability range as possible, we should include aspects of (g).

The above approach is very much a science to technology approach. Lets now consider the alternative approach.

(b) From technology to science

Van Aalst (1980) suggests that it would be desirable to establish a hierarchy of goals in science education based on the prime importance of learning experiences relevant to real life situations. His suggestion, as a starting point for discussion, is that this hierarchy should be from practical technological skills to complex scientific thinking skills - the children's progression to these higher skills being dependent on interest and ability. We move from technology to science, rather than the previously suggested approach of moving from science to technology.

If we were to follow this approach what would our hierarchy of aims look like? Below we consider a tentative list, adapted from the initial ideas of Van Aalst, as a basis for discussion.

(a) Functional everyday skills

e.g. . the ability to read meters and repair electrical plugs
. the ability to observe carefully and measure accurately
. understand instructions for the use of technical apparatus and for carrying out manipulative tasks.

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13 This example is an interesting one in that the scientic view, that water is in the air but can't be seen rather than that it has changed into air, is unlikely to be thought of by students. However some students, even aged 10 or 11 are really intrigued by the phenomenon and want an explanation. It would seem not unreasonable to "sow the seed" of a scientific idea perhaps introducing it first as the idea of a child in another class or even as the idea of a group of men - not as an idea simply to be learnt.

(b) Functional recognition skills

e.g. . the ability to understand and interpret tabulated and graphical information
. the ability to wire a circuit given a circuit diagram
. understand newspaper tables and explanations of technical and natural phenomena

(c) Functional understanding skills

e.g. . the ability to suggest explanations for observed phenomena
. the ability to consider and evaluate opposing explanations
. understand, and appreciate, scientific explanations for familiar natural phenomena and everyday technological equipment.

(d) Functional productive skills

e.g. . the ability to apply scientific knowledge and scientific processes to solve a problem
. the ability to criticise an article or report on scientific grounds
. understand, and be able to generate understandings within, the knowledge structure of a particular discipline.

It would seem appropriate that the level (d) objectives would only apply to the senior secondary school and the university levels of education.

If we were to teach within the Van Aalst framework what does this suggested hierarchy imply in terms of designing a particular lesson? Let us return to the topic of water vapour in the air for 11-13 year old children. Perhaps this time we would start by pointing out the humidity readings in the daily newspaper. We might discuss the effects of this thing called humidity on humans and tell pupils that it is all to do with the amount of water in the air (in droplets so small we can't see them!). From this introduction we would get students to use some sort of

hygrometer (an instrument which measures the amount of water in the air.)[14]

* We would encourage students to cope with instructions for its use.
* We would encourage them to take readings and record their data.
* We would encourage them to extract the humidity reading from the local paper, and to tabulate or graph the information.
* We would encourage pupils to think about how this water gets into the air and what happens to it.
* Some pupils might investigate and explore their ideas by deliberately attempting to change the humidity in the room.
* We would want to consider the effects of water in the air, high humidity has a variety of effects on humans, things are difficult to dry, and so on.

(c) Which approach?

In the above discussion we considered two approaches to the teaching of technology and science. Which approach would be preferable in any particular situation undoubtedly depends on a multiplicity of factors e.g. the teacher, the pupils, the resources and the possible need for a variation in approach. Are there other possible approaches? Undoubtedly there are.[15] However it is hoped that the two approaches discussed previously will provide a sufficient basis for discussion.

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14 This particular topic may well be not a very suitable or practical one; certainly in terms of equipment which is familiar to children and currently available in schools. Nevertheless the teaching sequence is pursued so that it can be compared with, and contrasted against, the teaching sequence discussed earlier.

15 For example we have found that children's views are often similar to early ideas held by the Greeks or 14 Century Europeans. For certain topics an historical analysis of the various views held by thinkers and scientists and the reasons why they held those views may result in pupils modifying their own views in the light of their historical research. It would seem to us however that such an approach is only likely to interest the academically oriented pupils.

THE ACTION RESEARCH PHASE

It is with the wealth of data from the first two phases of the project, along with the issues tnat they raise and which we have touched on in this paper, that we move into the final action research phase of the Learning in Science Project. Rather than being in a position where we feel we have identified some basic problems for which we can provide simple and effective answers, we feel conscious that the issues we have discussed with teachers and pupils and raised ourselves, are not easily resolved and certainly not by us alone.

We see our task in the action-research phase as two fold.

(i) Our first task is to continue and extend our dialogue with teachers and curriculum developers about the problems that have been raised. Only by getting a wide acceptance of them as problems, and by arousing the enthusiasm of teachers and others for attempts to solve them, will our work have any long-lasting effect. Already a number of teachers throughout the country have been interested in our concerns and are trying innovative teaching approaches in an attempt to overcome specific issues raised by earlier working papers.

(ii) Our second task is to work with groups of teachers in the Waikato; to discuss with them which of the issues raised in particular areas they consider important and possibly solvable problems, to explore ways whereby these problems might be solved or at least alleviated in the classroom, to actually try out innovative procedures suggested by members of the group or others, and finally to report on this work in a way which will clearly indicate to others the potential and the problems of the particular innovations attempted.

At present we envisage four groups;

(a) a physics group, exploring issues raised in the working paper FORCE, FRICTION and GRAVITY

(b) a biology group, exploring issues raised in the working papers
LIVING, ANIMALS and PLANTS

(c) a chemistry group, exploring issues raised in the working papers
PHYSICAL CHANGE, CHEMICAL CHANGE and PARTICLES

(d) an experimental skills group, exploring issues raised in the working papers
FOCUS ON EXPERIMENTS and FOCUS ON PROCESS SKILLS

Depending on manpower and other factors a fifth group may be formed later in the year.

We hope that our particular choice of focus, influenced by the resources available to us and by our earlier work will not limit other teachers, or groups of teachers in other areas, choosing either the same or different topics to the ones we are working on.

Finally, let us set out some of our ideas as a set of rules which may be useful in planning instructional sequences.[16] At the least we believe they are worth serious consideration.

1. The instructional sequence should where possible initiate from the knowledge structure which is already possessed by the pupil, i.e. pupils views will need to be established as part of the approach or be predictable on the basis of earlier research.

2. The instruction should illustrate explicitly how new meanings which pupils are confronted with compare and contrast with other previous meanings (especially more restricted versus more general meanings) and provide the opportunity for pupils to test or compare alternative explanations through 'hands on experimentation'.

3. The instructional sequence should promote cross-referencing of learning content by relating a concept to other concepts and principles e.g. contrasting electric current with electrical energy and emphasizing that electric current is the same in all parts of the circuit. Also by exploring many instances and non-instances.

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16 Adapted from a list by Wiestra(1980)

4. The instruction should explicitly relate subject matter being discussed to daily life experiences and to industrial and technological applications.

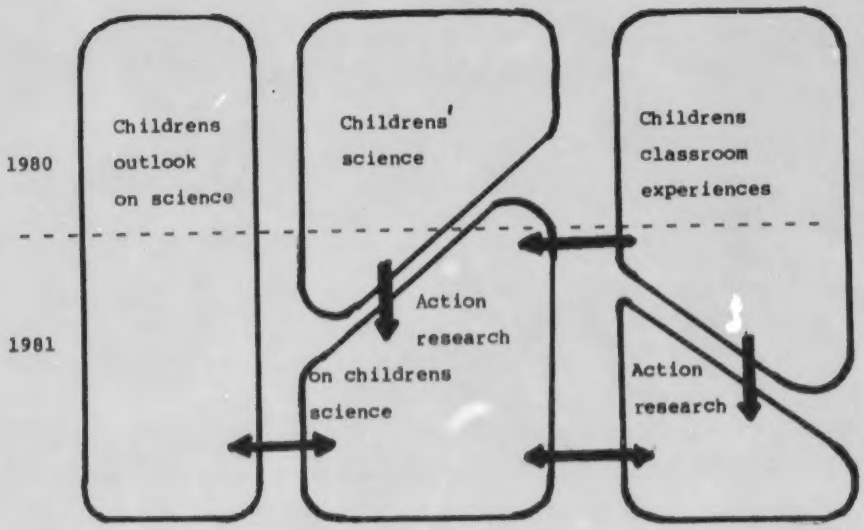
5. The instruction should be sufficiently adaptable so that those who cannot cope with abstract scientific ideas still find their experiences of science classrooms a challenging and worthwhile one.

Herein lies the challenge to us all.

Table I: The Topics of the In-depth Phase

		RESEARCHERS	ASSOCIATED PAPERS, ETC
			Freyberg & Osborne (1980)
CHILDRENS SCIENCE			Osborne (1980)
			Freyberg (1980)
16	FORCE	OSBORNE	Osborne & Gilbert (1980)
19	FRICTION	STEAD K/OSBORNE	Stead K. & Osborne (1981a)
20	GRAVITY	STEAD K/OSBORNE	Stead K. & Osborne (1981b)
17	ENERGY	STEAD B	Stead B. (1981)
26	PHYSICAL CHANGE	COSGROVE/OSBORNE	
27	CHEMICAL CHANGE	SCHOLLUM	
18	PARTICLES	HAPPS	
25	ELECTRIC CURRENT	OSBORNE/WILKINS	Osborne (1981)
22	ANIMALS	STEAD B.	Stead B. (1980a, 1980b)
24	PLANTS	STEAD B.	Stead B. (1980a)
15	LIVING	STEAD B.	Stead B. (2980a)
21	WEATHER	MOYLE	
23	LIGHT	STEAD B/OSBORNE	Stead B & Osborne (1980)
CHILDRENS' CLASSROOM EXPERIENCES			
28	A VISIT TO ANOTHER CLASSROOM	TASKER/OSBORNE	Tasker & Osborne (1980)
			Tasker (1980a)
			Tasker (1980b)
OVERVIEW PAPERS (about the Project in General)			
14	RECONSIDERING THE FRAMEWORK	OSBORNE et al.	Tasker et al. (1980)

Table II, The Learning in Science Project programme 1980/81



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Appendix Einstein on Scientists and Science

The following quote attributed to Einstein, (Lochhead and Clement, 1978) is about scientists and science. We would consider it equally true of children and learning science: We are all human. The emphasis is ours.

> The eyes of the scientist are directed upon thse phenomena which are accessible to observation... In an attempt to achieve a conceptual formulation of the confusingly immense body of observational data, the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk; and seldom if ever is he aware of the externally problematic character of his concepts. He uses this conceptual material, or speaking more exactly, these conceptual tools of thought, as something obvious, , ... given, something having an objective value of truth which is hardly ever, and in any case not seriously, to be doubted ... And yet in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not be unconsciously ruled by them."(p 34)

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LEARNING IN SCIENCE PROJECT

TOWARD SOLUTIONS:

The work of the Biology Action-Research Group

University of Waikato
Hamilton, N.Z.

69

WORKING PAPER No. 29

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Related LISP Papers

No. 15 Living
No. 17 Energy
No. 22 Animal
No. 24 Plant
No. 30 Animal, plant, living: notes for teachers.
No. 31 Teaching about animal, plant, living.

TOWARDS SOLUTIONS: The Work of the Biology Action-Research Group

Robyn Boe, Roger Cox, Beverley Bell

November, 1981

NOTE: THIS PAPER NEEDS TO BE READ IN CONJUNCTION WITH WORKING PAPERS 30 AND 31.

1. THE PROBLEM

Many of the students in science classrooms, despite up to four years of formal science tuition, have not developed a scientifically acceptable concept of 'living', 'animal', or 'plant'. These students have a wider meaning and use of the word 'living', and narrower meanings and uses of the words 'animal' and 'plant', than would a scientist. (A fuller description of children's concepts of 'living', 'animal', and 'plant' is given in Appendix A). One possible explanation of this discrepancy in meanings despite teaching, may be that teachers have assumed that students have and use the scientific meanings of 'living', 'animal', and 'plant'. Consequently, they have not focussed their teaching on them.

2. THE ACTION-RESEARCH PHASE

With this problem having been identified, LISP action-research was launched to explore with teachers some possible teaching strategies aimed at modifying the pupils' concepts of 'living', 'plant' and 'animal' towards scientifically acceptable ones.

With this aim, the Action-Research Biology Group was established in February, 1981.

2.1 The Group

The members of this group included two primary teachers; two science teachers from Form 1-7 schools; four secondary science teachers - two from large, city co-ed colleges, one from a medium size rural college, one from a small, single sex city school; two science advisers; and two LISP team members. Hence, teachers from all levels of primary, intermediate and secondary education were represented.

2.2 The Research Programme

Prior to the first meeting (13 March, 1981) group members received copies of the LISP Working Papers on Living, Plants, and Animals and Energy to acquaint themselves with the in-depth phase work that had been done in this area. This background information stimulated discussion about the problems in the first meeting of the group.

In the weeks following this meeting each of the members explored the problems in their own schools and devised possible methods of resolving them.

The thoughts and experiences of each member were shared in meeting two (24 April, 1981). It was widely appreciated that students do have concepts based on their own experiences (but invariably these were not scientifically acceptable).

Therefore, it was felt that it was not so much a case of teaching the scientifically acceptable concept, but rather setting up a learning environment which forces the student to challenge his/her own concept, and eventually, finding it to be inadequate, to see the need to modify it.

Two components considered important in such a learning environment were:

(a) physical acts of categorisation of instances and non-instances by the students;

(b) group discussion centred around the reasons for the student's categorisation.

The collective teaching ideas discussed at the second meeting were written up into a booklet, titled "A Trial Booklet of Suggested Teaching Activities", (see Working Paper No.31 for a full description). The activities in the package included:

- categorising things by sorting examples
- detective puzzles
- true-false quiz
- classification into sets and subsets (words only)
- group discussions.

In addition, in the primary area emphasis was given to an integrated programme using activities in music, drama, mathematics and art. The emphasis of the activities was to promote the development of the scientific concept.

To gauge the effectiveness of these teaching activities, a survey was conducted of pupil concepts before and after the learning experiences. Fourteen teachers from eight schools trialed the activities at most levels of primary and secondary education. The teaching experiences and science background of these teachers varied. (Details of the research programme and the package of activities and surveys are given in Appendix B).

At the third meeting, on 24 July, 1981, the results from the pre- and post-teaching surveys were presented. The teaching activities and other aspects of the action-research were discussed in depth.

2.3 Results and Discussion

2.3.1 Pre-teaching Surveys

The results of the pre-teaching surveys used by group members with classes in their schools are illustrated in Figures 1, 2, 3, 4, and show which scientific examples and non-examples of 'living', 'animal' and 'plant', students of varying ages, (new entrants to Form 6) also considered to be 'living', an 'animal', and a 'plant'.

These results support the findings of the in-depth phase that many students over-extended the concept of 'living' (Fig. 1) and have a restricted concept of 'animal' (Fig. 2 & 3), and of 'plant' (Fig. 4).

Students of all ages, correctly categorised the bird, person, cat and butterfly as living from a scientific viewpoint (see Figure 1). A U-shaped trend was apparent for the results of students' categorisation of the fire, sun, cloud, car and grass. The younger students (aged 5, 6) categorised the instances in a way similar to that of a scientist. For example, approximately 85% of the young students indicated that the sun

and the cloud were not living. However, more than 50% of Standard 3 and 4 students (aged 9, 10) thought the sun and fire were living. The concepts of the senior students (Form 5, 6; aged 15, 16) matched more closely with concepts of scientists with respect to examples and non-examples.

The results of the categorisation of the river are confusing as many students considered the river as living because of the living things which it could contain and support, e.g. fish, water weeds.

A possible explanation for the initial negative shift with age for the categorisation of the sun, fire, cloud, and car may be the emphasis in English language lessons on myths, legends and imagery when the metaphoric meaning of the word 'living' is focussed on rather than the scientific one.

Most students of all ages considered the large, four-legged, terrestrial mammal, the horse, to be an animal (see Figures 2, 3). The scientific non-examples of the concept 'animal', the fire and the pinetree were correctly categorised by most students.

As the students' age increases, they are more likely to categorise a person as an animal. This may be related to the developmental stages in which children become less egocentric and anthropocentric as they become older.

A U-shaped trend was apparent in the students' categorising of all the animals (from a scientific viewpoint) which were not large, terrestrial and four-legged. The concept of 'animal' which many of the 5 and 6 year old students hold was closer to the scientifically acceptable view than that of students who had had three or four years of schooling. From Form 1-2 to Form 6 more and more students categorised the instances of worm, spider, dolphin, moth, seagull, and fish as animals.

It appears that teaching may shift students' concepts away from the scientific one, especially at the primary level. This may result from the emphasis in primary school science on the study of animal groups, e.g. birds, in isolation, and without reference to the biological hierarchical classifications. These results give support to the findings of the in-depth phase that insects, birds, fish, etc., were not seen as subsets of animals, but rather as comparable sets to the set of animals. These results also reflect the common usage of the word 'animal' as synonymous to 'mammal'. The slow shift towards the scientific concept after Form 1 - 2 may be in part due to the overview and wider perspective of the ecological emphasis of the biology units, presently in the Form 1-4 syllabus.

Students' concepts of 'plant' matched the scientific concept more closely than the other two. A U-shaped trend in the results was present for some instances but it is not a marked trend (see Figure 4). In general terms, some students in a science class may not be able to classify the instances as a plant, or not, as would a scientist. The atypical result was that of the categorisation of the carrot, especially for students aged 5, 6 and 16. The fact that the carrot may have been categorised as a vegetable, its colour, and that it grows as a fleshy root underground may have influenced the students' thinking.

In summary, in most science classes, many students aged 5 to 16 years, do not have or use a scientifically acceptable concept of 'living', 'animal' and/or 'plant' with respect to examples of the concept. Also young students (aged 5) and older students (aged 16) appear to have a concept of 'living', 'animal', and 'plant' that more closely matches the scientific one than students at the upper primary, intermediate, and junior secondary school levels.

2.3.2 The Results of the Teaching Episodes

The effectiveness of the teaching unit was assessed by comparing the results of the pre- and post-teaching surveys. These survey results indicate the changes in the number of students answering the survey as would a scientist.

Two representative results from a total of eight results on teaching focussed on 'living' are illustrated in Figures 5a, b; three representative of a total of ten results on 'animal' are illustrated in Figures 6a, b, c; and three representative of a total of six results on 'plant' are illustrated in Figures 7a, b, c.

Living

At both the standard 3/4 level (see Fig. 5a) and Form 3 level (see Fig. 5b) more students categorised the instances in the post-teaching survey as would a scientist. This increase was more noticeable at the Standard 3/4 level. This may reflect the teaching style of the teacher or the age factor. Gains were not so marked with the Form 3 sample for the fire, cloud, sun and river. Even after teaching focussed on the concept of 'living', some of these older students still over-extended the scientific concept and categorised the fire, cloud, sun or river as living, thus displaying animistic, or metaphoric, thinking. As discussed earlier, the river gave rise to confusion as it was seen by many students to be living because of the living things it contained.

In discussion with the students after the post-survey was completed, it became apparent that they had difficulty in considering more than two characteristics or variables simultaneously. This means that they selected only the salient features from the list of seven characteristics of living things coded by the mnemonic "M.R.S.G.R.E.N." (Movement, respiration, sensitivity, growth, reproduction, excretion, nutrition), and cells. For example, the cloud was seen to be living because it moved or grew in size. Other characteristics such as respiration or possession of cells were not considered.

The non-instance of fire was seen to have all the "M.R.S.G.R.E.N." criteria, i.e. it moves, it needs oxygen, it responds to air movements, it can increase in size, sparks can start new fires, it produces wastes, and needs fuels. Cellular structure is the only criterion common to living things which a fire does not possess, but this was often not considered.

In our view there would be less confusion, if, when teaching the concept of 'living', teachers concentrated on clarifying the scientists' meanings for animals and plants and then used the idea of "if it is a plant or an animal, then it is living". This reduces the number of characteristics which a student needs to handle simultaneously whenever a categorisation is being made.

Animal

The results on the teaching on 'animal' are illustrated in Figures 6a, b, c and illustrate an increase in the students answering the survey as would a scientist. In other words, more students, at three different age levels, were able to demonstrate after the teaching that they had a scientific concept of 'animal'. The survey does not, however, indicate if the students appreciated the two meanings of the word animal (the everyday restricted one and the scientific one). However, in terms of science education, the teaching had been successful in promoting the scientific meaning.

Plant

Similar increases in the number of students using the scientific meaning of 'plant' after the teaching unit, are illustrated in Figures 7a, b, c.

2.4 Implications of the Results for Science Education

1. Teachers need to be aware of the possible communication problems if they and their students attach different meanings to the words 'living', 'animal', and 'plant'. They cannot assume that their students have and use scientific meanings for these words. The instructions "collect two different animals and put them in a jar", may be interpreted differently by the teacher and the student.

2. Teaching activities focussing specifically on these concepts do help students develop scientifically acceptable concepts of 'living', 'animal' and 'plant'. The length of time spent may vary from 2-3 weeks in the primary school to 1-2 periods in the senior secondary school. While the focus of the teaching may change (see Appendix B) there is a need to revisit these 3 concepts at different age levels (primary to secondary).

3. Other research [Barker, M. (1981) unpublished Dip.Ed. thesis, Massey University] has shown that students who have and use a scientific concept of 'animal', develop a scientific concept of consumer more readily than students who have a restricted concept of 'animal'.

Two third form classes were pre- and post-tested about their concepts of animal and consumer (Figures 8 and 9). The control class received 'normal' lessons on consumers, producers, decomposers, etc., while the other class (experimental) were taught what an animal is in the scientific meaning of the word. Only at the end of the lesson was the concept of animal related to the concept of consumer. The results in Figure 9 illustrate the effectiveness of being aware of children's ideas and teaching accordingly.

The results also suggest that the difficulties students experience with the abstract ecological concepts, now emphasised in the Form 1-4 syllabus may be in part due to students not having scientifically acceptable concepts of basic ideas, such as 'living', 'animal', and 'plant'. It may be more efficient to focus on these basic concepts in science lessons prior to Form 3/4 and leave teaching on ecological concepts until the later secondary level.

4. Teaching focussing on the characteristics (criteria) of living things animals, and plants may be best left until the junior or even senior secondary level. The scientific criteria are often abstract ideas themselves, e.g. respiration as a characteristic of living things; autotrophic feeding and cell structure for plants. The traditional characteristics of living things (M.R.S. G.R.E.N.) may promote animism in students, especially with such instances as the fire and sun. Therefore, teaching, prior to Form 3, would emphasise the categorisation or examples and non-examples of each concept only.

3. FINAL OUTCOMES OF THE ACTION-RESEARCH GROUP WORK

As a result of the above work two booklets for direct use by teachers have been prepared. The first booklet is a summary of the in-depth phase work and it is written to help teachers appreciate both children's views and the scientists' views on animals, plants and living.

The second booklet arises directly out of the action-research phase work and is a booklet of suggested teaching activities for use by teachers at all levels. It is a modified version of the initial trial booklet of suggested teaching activities.

Currently these booklets are available as Working Papers of the Learning in Science Project.

(a) Animal, Plant, Living.
Notes for Teachers
Working Paper No. 30, Learning in Science Project.

(b) Teaching about Animal, Plant and Living.
Suggested Teaching Activities
Working Paper No. 31, Learning in Science Project.

APPENDIX A: Relevant Work of Earlier Phases of LISP

1. The Learning in Science Project

The Learning in Science Project (LISP) was established in February 1979 to make a detailed study of the teaching and learning of science at the Forms 1-4 level; to identify some of the key difficulties, and to investigate possible ways of helping to overcome such difficulties. It was hoped that the project, through objective research, could provide information on which further science syllabus modifications could be based.

To achieve the project's aim a three-step programme was adopted:

"(a) an exploratory phase to observe the teaching and learning of science in classrooms and to identify difficulties as perceived by teachers, pupils, and experienced classroom observers;

(b) an in-depth phase to focus on the teaching and learning of selected aspects of the science course, for example, topics or themes; and

(c) an action-research phase, based on the findings of the first two phases, to explore with teachers possible ways of overcoming the identified difficulties and problems in teaching and learning science."

This working paper relates to the research on the teaching and learning of biology in Forms 1-4.

2. Results of the Exploratory Phase indicated that:

(a) Most of the pupils and teachers interviewed enjoyed biology.

(b) Many teachers were more confident about teaching the biology units than the physics and chemistry ones. However, classroom observations indicated that difficulties experienced by teachers, are not always realised by them. Teachers' confidence may be due to their familiarity with the common, not biological, meaning and use of many words.

(c) Some teachers and other people concerned with science education expressed concern at the placement of ecological concepts in Forms 1-4 biology curriculum. In particular, the ecological concepts were felt to be too abstract for children of that age, and that the children lacked the prerequisite knowledge of individual animals and plants to undertake a study of ecology.

The results of an in-depth phase investigation (see Working Paper No.17) indicated that children's meanings for the word 'energy' are limited and illustrate an inability to cope with the abstract concept of energy even at the Form 5 level. The appropriateness of including ecological studies, in their present form in the Forms 1-4 science syllabus was again questioned. But what is appropriate? To clarify this issue, we need to be aware of what concepts the pupils already hold, and work from this base.

Three concepts basic to a study of ecology, and in fact biology, are 'living', 'animal' and 'plant'. Their common usage in biological texts and lessons implies that pupils do have meanings or concepts to attach to these labels. But what concepts do pupils have and how similar are they to the scientifically acceptable ones? (See Working Paper No.30 for a description of the scientific concepts). The in-depth phase of the programme focussed on these questions.

3. Results of the In-Depth Phase

There are two aspects of the meanings students have for the word 'living', 'animal', or 'plant'. Firstly, what do students consider to be examples of living things, animals and plants? Secondly, what reasons or characteristics do students use to categorise something as living or not-living, animal or plant?

The results of the in-depth phase may be summarised as:

3.1 Students' meanings of the word 'living' (See Working Paper No.15 for a full account)

Many students have a wider meaning of the word 'living' than that used by a scientist. They have more examples of living things than would a scientist. Some students consider a fire, cloud, river, car, bike and the sun to be living whereas a scientist would not.

Some of the reasons used by students to classify something as living or non-living are acceptable to scientists, e.g. movement, feeding, growth, senses, reproduction, cells. However, th[illegible] reasons are also used to classify as living, things that a scientist would consider non-living, e.g. cloud, river, fire.

Some students use reasons that would not be used by a scientist to categorise something as living, e.g. gives off energy, makes a noise, usefulness.

However, we as adults, also use this wider meaning of the word 'living' when we use this word in a metaphoric sense. For example, we talk of the 'living bible', or of the 'living flame' in advertisements for natural gas. We use the word as if the bible or flame was living. We may not consider the book or flame to be living from a scientific viewpoint but we may consider it living in a metaphoric sense, as if it was living.

If we are to understand the message in such phrases we must interpret the word 'living' in the metaphoric not scientific sense. Science teachers, may need to clarify to the students, which is the appropriate meaning to use in different situations.

3.2 Students' meanings of the word 'animal' (See Working Paper No.22 for a full account)

Many students see animals as only the large land mammals, such as those on a farm, in a zoo, or jungle, or in the home as pets. Their range of examples of animals is narrower or more restricted than that of a scientist. Many students, including Form 5 and 6 students did not consider a worm, a spider, or a fish, for example, to be animals whereas a scientist would.

The reasons used by many students to categorise something as an animal differ from those used by a scientist. Examples of such reasons are number of legs, size, habitat, fur.

Other reasons used by students are similar to those used by scientists to decide if something is an animal or not. Examples of these reasons are movement, a nervous system, and mode of feeding.

We as adults often use this restricted meaning when we use the word 'animal' in an everyday sense. A scientist considers people as animals as they are consumers, move, have a nervous system, sense organs and have cells without cell walls. However, many food shops display the sign

"No Animals Allowed".

If we interpret the sign from a scientific viewpoint we cannot go in. To understand the intended message, we need to interpret the word 'animal' in the everyday or restricted sense, that is, meaning only cats, dogs, horses, etc. We as science teachers, need to clarify to students that there are two meanings for the word 'animal'. One (the narrower meaning) is appropriate to use in an everyday situation, and one (the wider meaning) is appropriate to use in the scientific situation (say in the science lesson).

3.3 Students' meanings of the word 'plant' (See Working Paper No.24 for a fuller account)

Many students have a narrower meaning of the word 'plant' than that of a scientist. Many did not consider the vegetables, the weeds and hard, large trees to be plants, as would a scientist.

Few students use the scientifically acceptable abstract reasons of producer feeding and cell structure to categorise something as a plant. The reasons used by students, while not characteristic of all plants, do pertain more to plants than to animals. Examples of such reasons are possession of leaves, flowers, stem, roots and immobility.

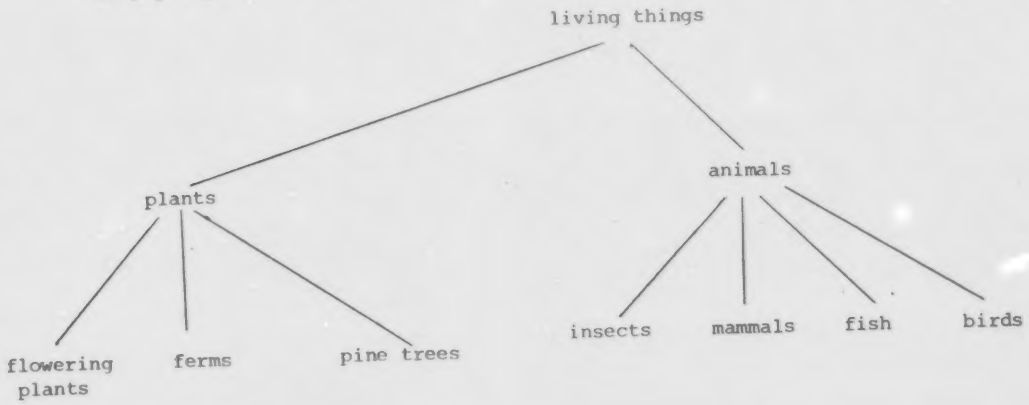
Some students do use reasons that are unacceptable to a scientist to categorise something as a plant or not, for example, size, hardness, cultivation.

As with the word 'animal' there appears to be an everyday meaning of the word 'plant' that has a narrower meaning than the scientific one. Science teachers need to clarify to students that there are two meanings for the word, and when it is appropriate to use each of these two meanings.

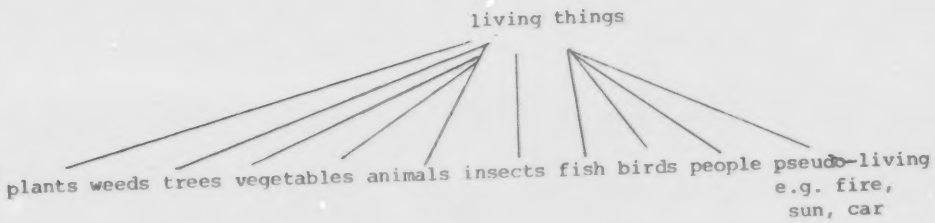
3.4 Summary

The meanings children give to the words 'living', 'animal' and 'plant' indicate that their hierarchial categorisation of living things may not be the same as that of a scientist.

For example, a scientist's categorisation of living things may be simply represented as:



For many students, the categorisation may be represented as



The biological subsets of trees, vegetables, weeds and of people, insects, fish and birds are seen as comparable sets to the sets of plant and animal, not as subsets.

In summary the findings of the work of the in-depth phase of LISP related to Biology found that children do have meanings for the words 'living', 'animal' and 'plant'. But these meanings are often different to the scientific meanings. Children often have a wider meaning of the word 'living' and narrower meanings of the words 'animal' and 'plant' compared to that of a scientist. These meanings used by children correspond to the metaphoric use of the word 'living' and to everyday use of the words 'animal' and 'plant'.

APPENDIX B: Details of the Action-Research Programme

Action-Research Guidelines

1. Read the Trial Booklet for Teachers - Animal, Plant and Living. This booklet describes why we need to focus teaching on these three basic words or concepts.
2. Decide whether to focus the teaching and learning on the living or animal/plant, or all three.
3. Administer to the class survey A of animal (Survey 1A), plant (2A) or living (3A) depending on which word(s) you decide to focus the teaching and learning on.

   Refer to the sheet labelled "Instructions for Administering the Surveys".
4. Record the results on a chart headed "Survey Results".
5. Consult the "Trial Booklet of Suggested Teaching Activities" and plan a teaching episode, taking into account the results of the survey.
6. Conduct the lessons on living, and/or animal and plant.
7. In a week following the last lesson, administer the B survey for the word(s) concerned - animal (1B), plant (2B), living (3B). Give only one survey per day to avoid confusion.
8. Record the results on the chart headed "Survey Results" in the appropriate column.
9. Complete the Feedback Sheets on
   i) the Trial Booklet for Teachers on Living, Animal, Plant,
   ii) the surveys,
   iii) the Trial Booklet of Suggested Teaching Activities.

Details of the Content of the Package Sent to the Action-Research Group Members

1. A pamphlet giving general information on the Learning in Science Project.
2. Action-Research Guidelines.
3. Trial Booklet for Teachers - Animal, Plant and Living.
4. Six overhead projector transparencies. These are the six master sheets of the surveys - animal, (surveys 1A, 1B); plant (2A, 2B); and living (3A, 3B).
5. Six answer sheets - one for each of the six surveys.

6. Instructions for Administering the Surveys.

7. A sheet, Survey Results, on which to collate the results of the survey.

8. A Trial Booklet of Suggested Teaching Activities.

9. Feedback Sheets on:

   i) the Trial Booklet for Teachers on Animal, Plant and Living,

   ii) the surveys,

   iii) the Trial Booklet of Suggested Teaching Activities.

APPENDIX B

THE FOCUS OF THE TEACHING AT DIFFERENT LEVELS

A PAGE FROM THE TEACHING ACTIVITIES BOOKLET.

Level 1 (J1 - J3)

increasing children's awareness of the things we call living things, animals, and plants by getting them to observe these different kinds of things.

Level 2 - 3 (Std.2 - Std.4)

(a) developing the skill of categorising.

(b) categorising things into the groups of living, non-living, dead and animal and plant as would a scientist.

Level 4 (Form I - II) and Level 5 (Form III - IV)

(a) and (b) as for level 2 - 3.

(c) contrasting the scientists meaning for these words with the metaphoric and everyday use of the words.

(d) the reasons scientists use for categorising things into living, non-living, animal and plant.

INSTRUCTIONS FOR ADMINISTERING THE SURVEYS

For each word or concept there are two surveys. The A survey for each word is to be given before the teaching and learning episode, and the B survey after.

APPENDIX B: An Example of the Six Surveys 3B

IS IT LIVING?

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

APPENDIX B: Survey Answer Sheet 3B

IS IT LIVING?

Put a tick (√) in one of the squares

1.	Is a truck living?	Yes ☐	No ☐
2.	Is the sun living?	Yes ☐	No ☐
3.	Is a cloud living?	Yes ☐	No ☐
4.	Is a seagull living?	Yes ☐	No ☐
5.	Is a dandelion living?	Yes ☐	No ☐
6.	Is a person living?	Yes ☐	No ☐
7.	Is a river living?	Yes ☐	No ☐
8.	Is a dog living?	Yes ☐	No ☐
9.	Is a moth living?	Yes ☐	No ☐
10.	Is a fire living?	Yes ☐	No ☐

Surveys 1A and 1B are about the word animal,
Surveys 2A and 2B are about the word plant,
Surveys 3A and 3B are about the word living.

Give only one survey per day (either 1A, 2A, or 3A; either 1B, 2B or 3B)

1. Hand out the answer sheets, one to each students. Check that the number, e.g. 1A, matches the number on the master sheet (the picture sheet).
2. Put the master sheet on the overhead projector. Explain what they are required to do and how they indicate their answer on the answer sheet.
3. The survey normally takes about 5-10 minutes to complete.
4. Collect in the answer sheets.

NOTE:

1. For the younger children either:

   (a) Go through the survey with individual children. Point to the picture on the master sheet and ask if it is an animal (or plant or living). The teacher then places a tick in the appropriate square on the answer sheet.

OR:

   (b) Go through the survey as a whole class but the students indicate their choice of answer by a show of hands. The teacher counts the number of hands for a 'yes' answer and for a 'no' answer, and records this on one answer sheet.

2. If no overhead projector is available, the master sheets can be photostated and a copy handed to each student.

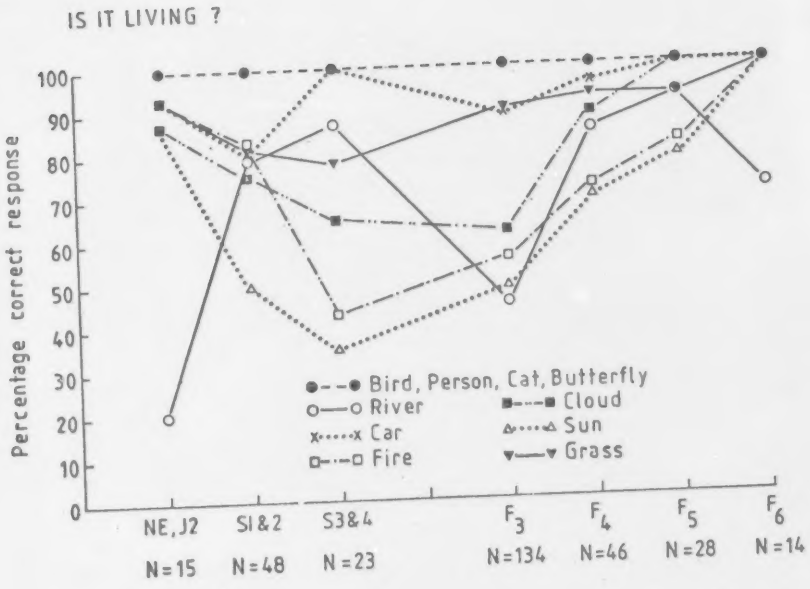


Figure 1. The Results of the Pre-teaching survey on'Living'.

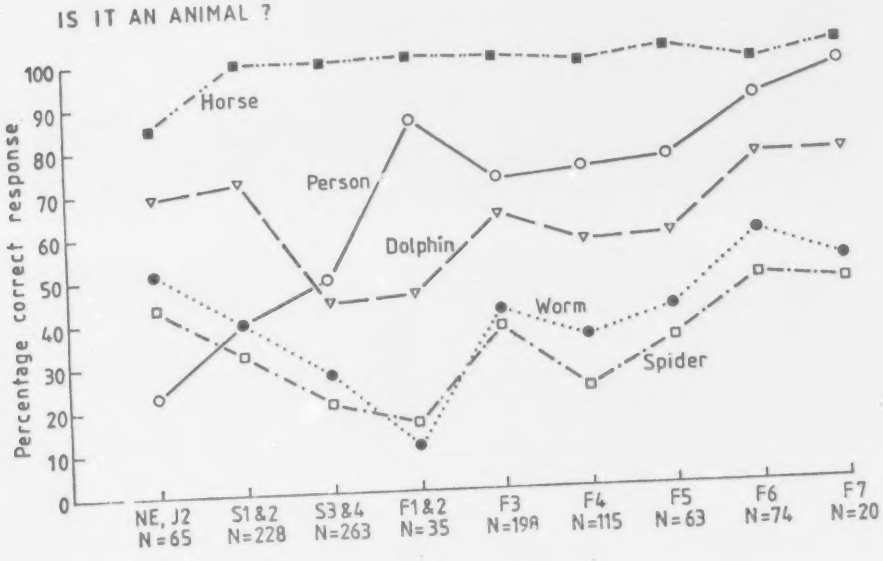


Figure 2: The Results of the Pre-teaching surveys on 'Animal' : Part 1.

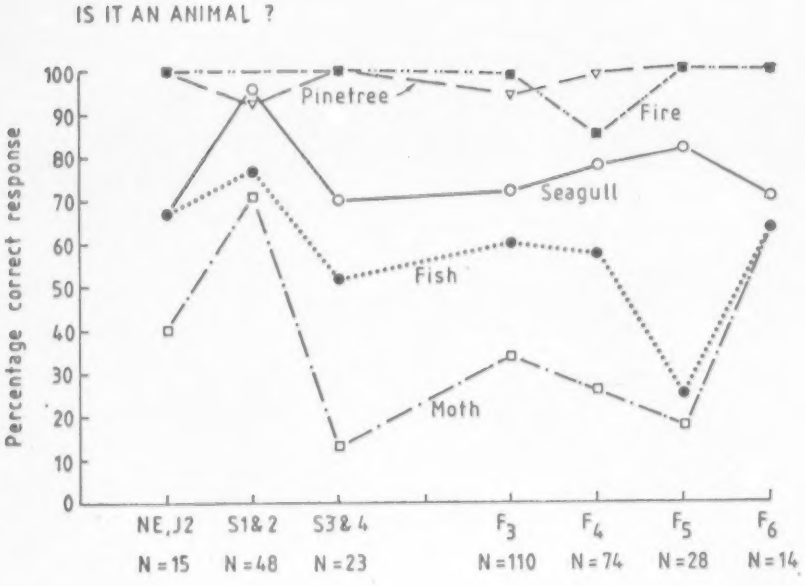


Figure 3: The Results of the Pre-teaching Survey on 'Animal' Part 2.

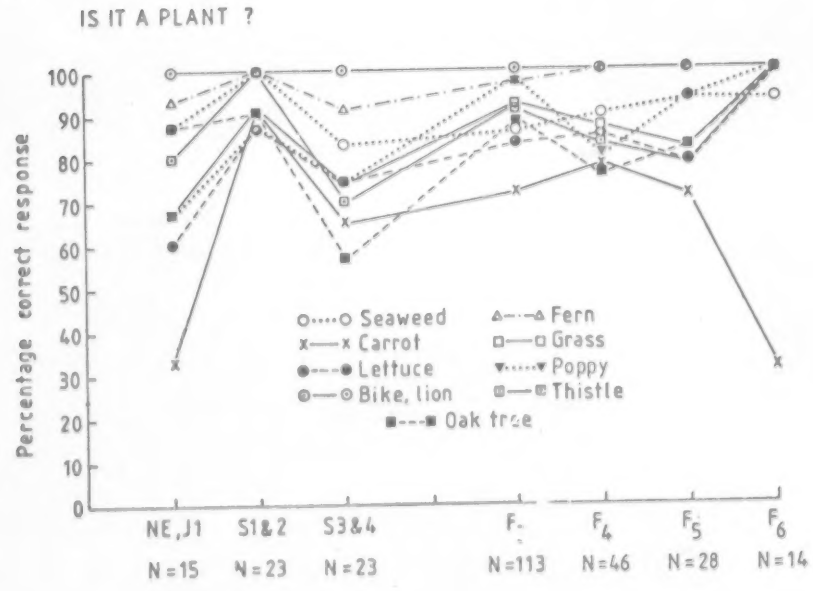


Figure 4: The Results of the Pre-teaching surveys on 'Plant'.

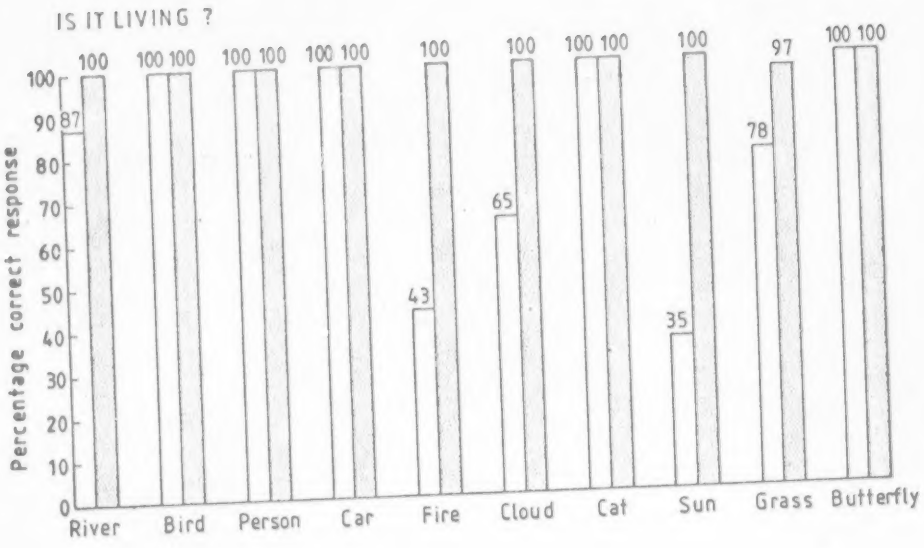


Figure 5a : The Pre- and Post-teaching Survey Results - Living (N=23, age 9/10,Std. 3/4)

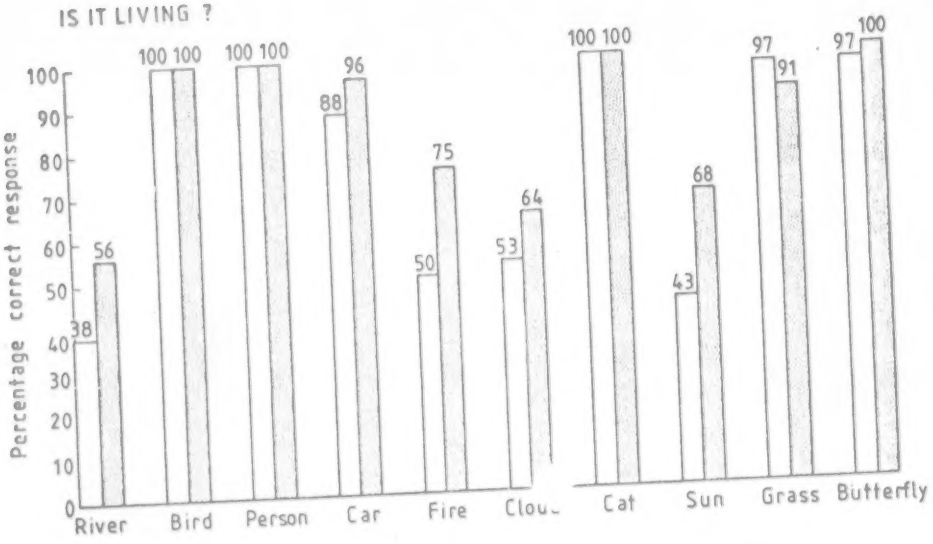


Figure 5b: The Pre- and Post-teaching Survey Results - Living (N=60, age 13, Form 3)

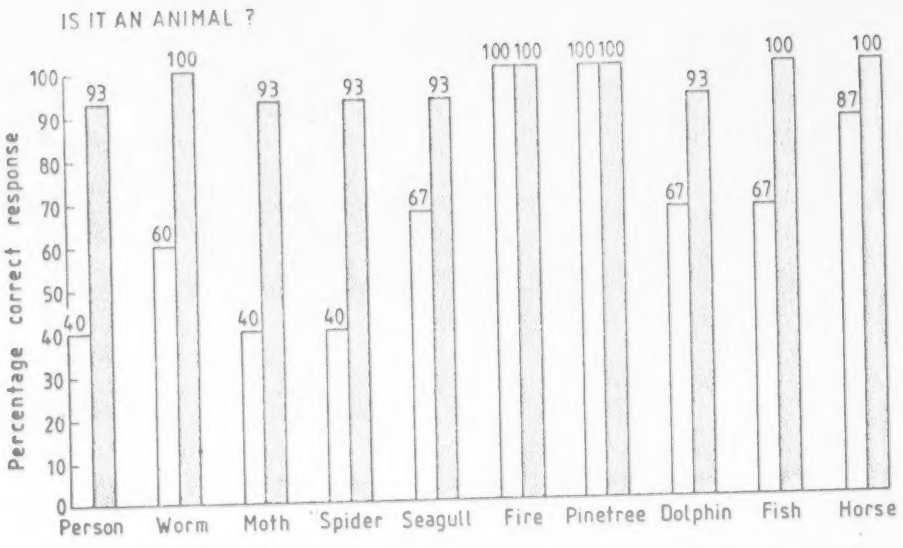


Figure 6a: The Pre- and Post-teaching Survey Results - Animal (N=15, age 5, New Entrants)

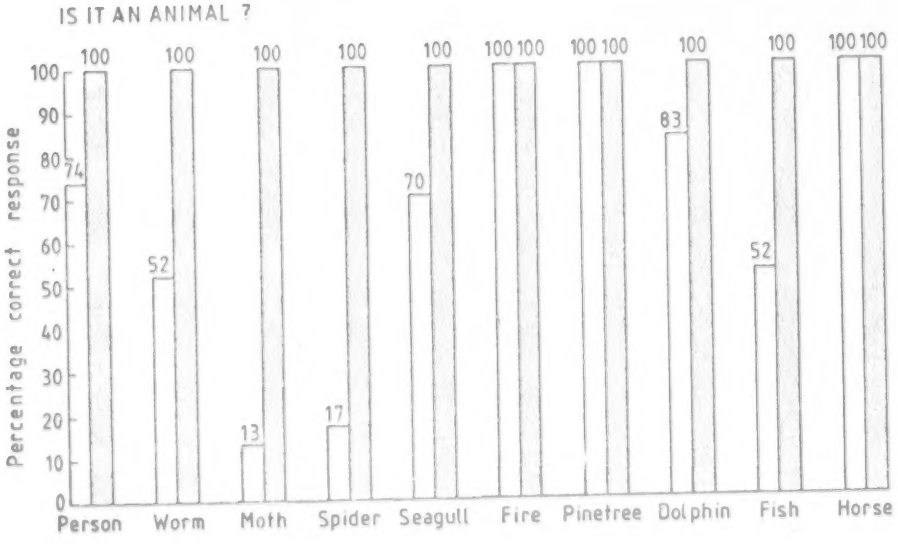


Figure 6b: The Pre- and Post-teaching Survey Results - Animal (N=23, age 9,10, Std 3/4)

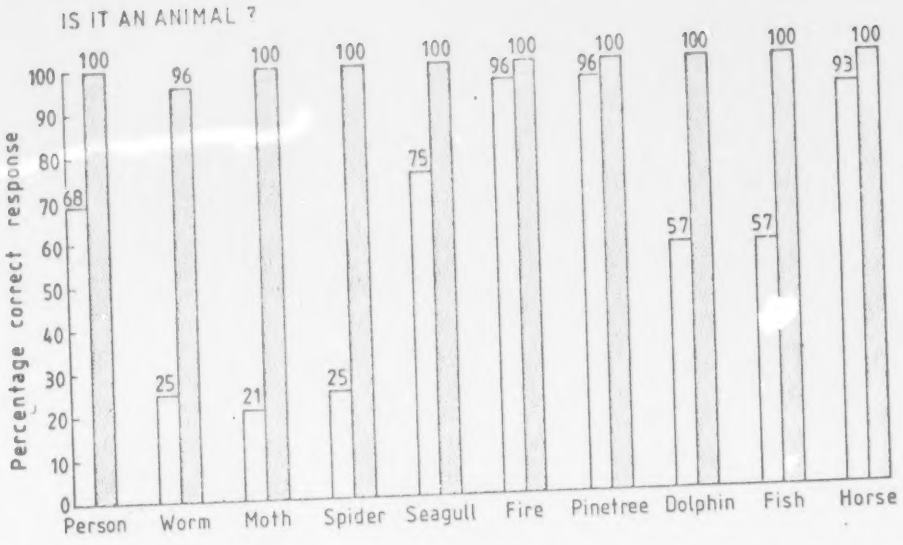


Figure 6c : The Pre- and Post-teaching Results - Animal (N=28, age 14, Form 4)

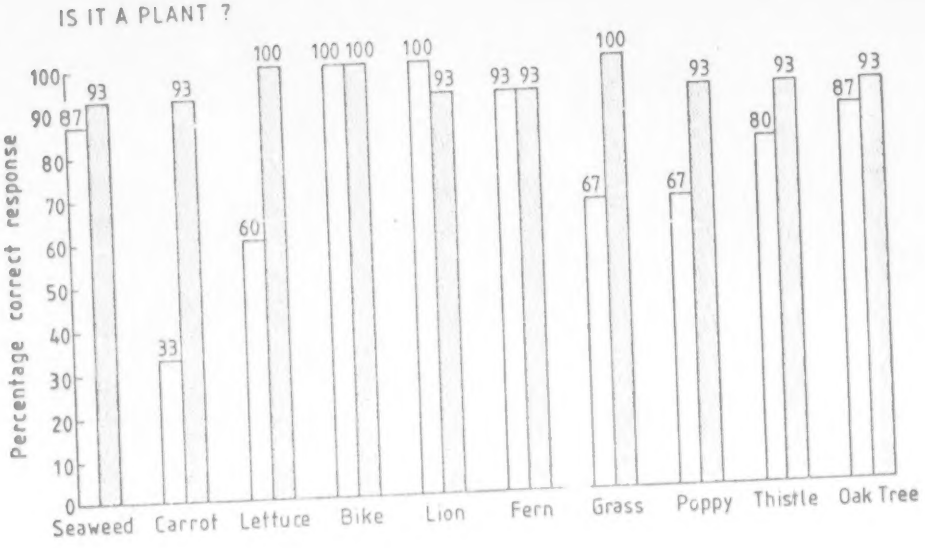


Figure 7a: The Pre- and Post-teaching Survey Results - Plants (N=15, age 5, new entrants)

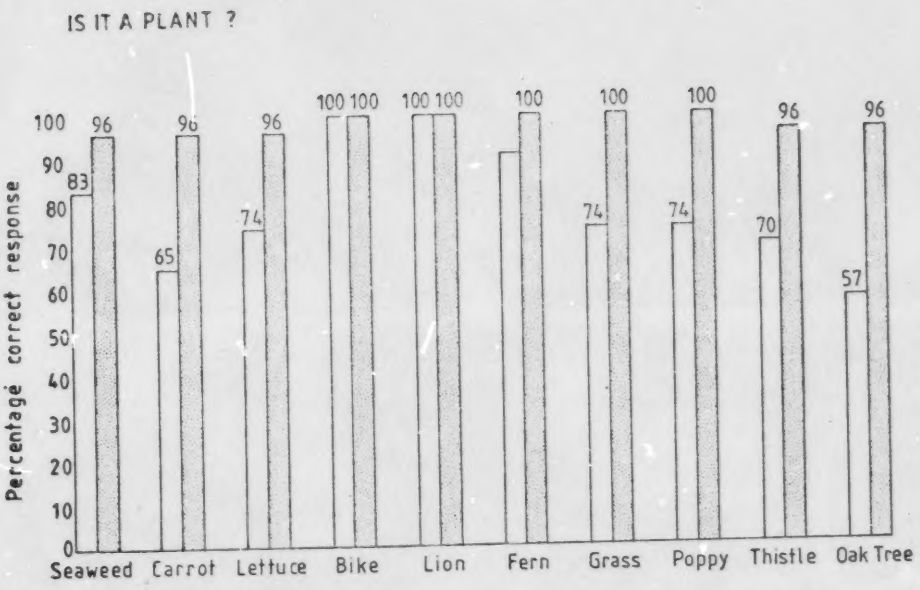


Figure 7b: The Pre- and Post-teaching Results - Plant (N=23,age 9,10, Std 3/4)

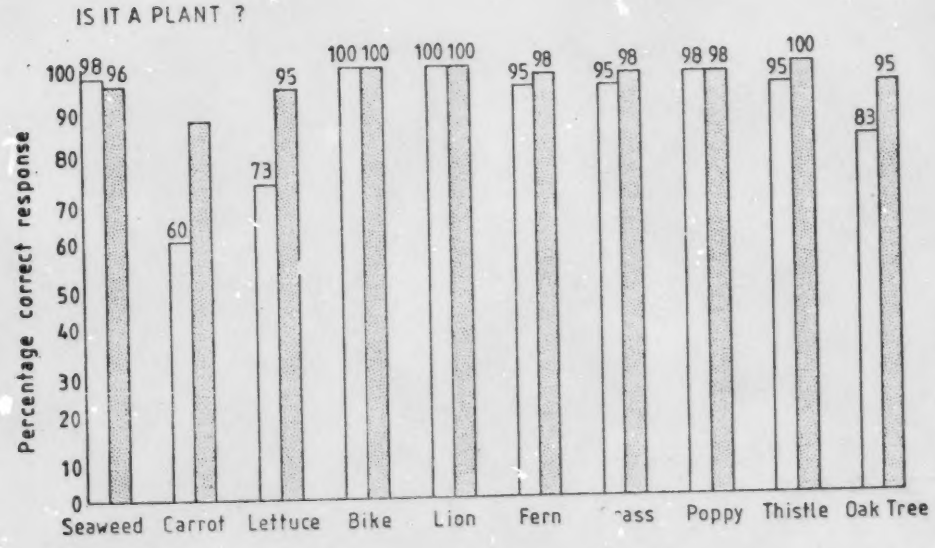


Figure 7c: The Pre- and Post-teaching Results - Plant (N=60, age 13, Form 3)

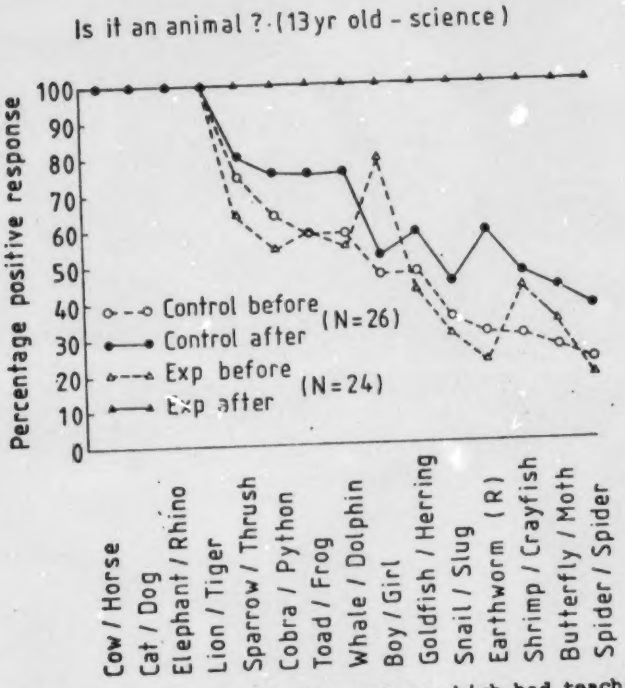


Figure 8: Pre- and Post-teaching results for a class which had teaching focussing on 'animal' (the experimental group) and a class which had no specific teaching on 'animal' (the control). (Barker, 1981)

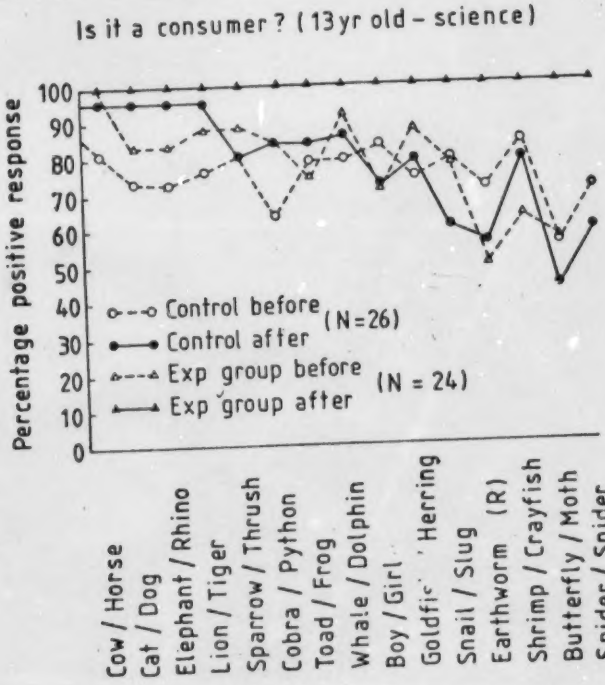


Figure 9: Pre- and Post-teaching results for a class which had teaching on the word 'animal' before that on the word 'consumer' (the experimental group).

LEARNING IN SCIENCE PROJECT

TOWARD SOLUTIONS:

The work of the

Physics Action-Research Group

University of Waikato
Hamilton, N.Z.

WORKING PAPER No. 32

PHYSICS ACTION-RESEARCH GROUP

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Our thanks to many others who helped with aspects of the action-research including in particular, Peter Freyberg, David Hood, Gillian Tasker and Colin Telford.

THE WORK OF THE PHYSICS ACTION-RESEARCH GROUP

Roger Osborne and Brendan Schollum

November 1981

INTRODUCTION:

In the action-research phase of the Learning in Science Project four groups of people worked on problems identified in the in-depth phase of the Project. The Physics action-research group considered problems related to the teaching and learning of ideas associated with force and motion; problems which had earlier been identified in three working papers, Force (No. 16), friction (No. 19) and Gravity (No. 20).

The group was chosen to provide a variety of experiences in teaching and a range of academic backgrounds in physics. It consisted of practising classroom teachers and Learning in Science Project team members. Prior to the first meeting of the group in February 1981 individuals were sent the three working papers of the in-depth phase - Force, Friction and Gravity, and asked to consider whether the problem and difficulties described in these papers related to real, important and possibly solvable issues.

THE FIRST MEETING

The initial meeting of the group was held early in the year. The group collectively agreed that the problems identified by the papers appeared real and important issues which have not been confronted by existing curriculum materials. The group, however, could not agree so readily on the age level at which efforts to solve some of the problems should be made. However it was generally accepted that the scientific view of force is basically a simple idea and one that is needed to be held by at least one group of children - our future scientists and technologists. It was also agreed that the scientists' concept of force is a central and basic topic in the understanding of science and the topic is certainly along the path children need to tread if they are to find out about the scientists' view of the world.

With respect to what might be done to resolve some of the problems identified in the force, friction and gravity papers a number of points were agreed to;

i) frictional forces, reaction forces and momentum are concepts that have been played down by teachers but they are fundamental ideas,

ii) a major priority must be to improve the teachers' understanding of both scientists' views on the one hand and children's views on the other,

iii) the opportunity must be provided for children to clarify their own views and for these views to be valued,

iv) scientific ideas about force, friction and gravity must be linked to the everyday experiences of pupils and, in teaching, there is a need to provide many examples and non-examples of any one concept.

THE SECOND MEETING

At the end of the first term the group met again. During the first term many members of the group had checked out whether or not the problems identified in the working papers were, in fact, problems in their own schools. The general consensus was that indeed they were - survey results they obtained with pupils in their schools were similar to the results reported in the working papers.

It would be fair to say that members of the group found some difficulty in suggesting innovative teaching strategies which might help to overcome the problems identified in the working papers. One suggestion put up by the LISP team however did appear to be worthy of investigation. The proposed teaching strategy, which will be explained more fully in the next section, was somewhat unorthodox. However it did appear to be centrally concerned with attempting to modify, rather than ignore, children's intuitive ideas. An outline of possible teaching activities based on the proposed strategy, which we will call the "force through momentum" approach, was developed and a number of members of the group and others agreed to trial the approach in their own classrooms.

About this time the type of material that might be produced for teachers, and others, by the action-research group was becoming clear. It was proposed that:

i) A booklet should be produced (Working Paper No. 33) which provided teachers with background information on typical children's views, and scientists' views, with regard to force, friction and gravity. The booklet should also provide teachers with the opportunity to clarify their own views with regard to these topics.

ii) A booklet should be produced (Working Paper No. 34) which would provide teachers with specific teaching activities directly useable in classrooms. These teaching materials should provide surveys to check on children's ideas both prior to, and after, teaching; material which would enable children to have classroom discussion about their ideas; and also worksheets and activities to enable pupils to have key experiences. Consideration should also be given to worksheets and explanations directly usable by pupils.

iii) In-service course material should be produced (Workshop Package - Force) consisting of video tape, OHP materials, discussion documents, as well as the booklets described under i) and ii) above.

THE TEACHING 'FORCE THROUGH MOMENTUM' IDEA

One of the major philosophical viewpoints arising from the work of the in-depth phase of the LISP work (see Working Paper No. 28) was that with respect to a number of topics in science, learning might well be more appropriately viewed as a modification of children's early intuitive ideas toward the scientists' viewpoint, rather than the absorption of scientific ideas by blank minds (see Gilbert, Osborne & Fensham, 1982). Many children's ideas about force, friction and gravity (see Working Paper No. 33) need modification if they are to more closely relate to the scientific viewpoint. However in our view one of the most central and important ideas that needs to be modified is the fact that the physicists' concept of momentum is intuitively appreciated by many children but it is labelled by children as a force.

Forces to physicists are basically pushes and pulls which act on an object, whereas to many children they are also quantities which are in moving objects by virtue of their motion and which cause the object to move forward (again see Working Paper No. 33). This suggested to us that children's ideas might well be most successfully modified if we,

i) build on children's intuitive idea of the physicists' momentum concept,

ii) introduce the label momentum for that concept, and

iii) separate out for children the distinct difference between momentum and force.

This is the basis of the force through momentum approach.

From a theoretical perspective there were two additional reasons why the momentum approach seemed worth trying. Firstly Raven (1967-8) showed that although from a logical analysis of the concept of momentum (momentum = mass x velocity) the most efficient learning sequence might well be conservation of matter ⟶ speed ⟶ proportional use of mass and speed with momentum held constant ⟶ momentum, it appeared from the study of young children that the psychological sequence of understanding was in fact momentum ⟶ conservation of matter ⟶ proportional use of mass and speed speed. Raven's findings supported our view that momentum was indeed a concept children already hold at quite a young age, (age 5^{+}).

The second reasons for placing emphasis of momentum relates to the teaching of physics at more senior levels. At senior secondary school and first year university levels, momentum is often introduced before force: Force is then defined as the rate of change of momentum with time, as suggested by Newton. More recently di Sessa (1980) has shown how many mechanics' problems can be solved using momentum ideas.

All the above therefore encouraged us to attempt to teach force through momentum ideas. An initial framework was developed and some of the teachers working in the group, as well as some of their school colleagues, adopted this framework and modified and expanded it into suitable teaching activities.

The resulting teaching sequence was a first draft of the activities provided in Working Paper No. 34. However some of the activities were modified substantially as a result of the trials (see later). Four teachers tried the material with a Form 1 class, two Form 3 classes and two Form 4 classes. Later the material was tried in a modified form with other Form 1-4 classes.

RESULTS OF THE TRIALS

The classes were surveyed prior to and after the teaching sequence using Survey A and then Survey B.[1] The reaction of the teachers to the teaching sequence was positive, they enjoyed teaching the sequence of lessons and pupils appeared to have no difficulty in appreciating the concept of momentum. As one teacher said;

> "I had no difficulty getting across the idea of momentum, it seemed that they already had the idea before I taught them."

This type of comment very much supported our ideas that it is so important to design teaching activities which build on, rather than ignore, children's views. However the results of the post-teaching survey were less encouraging. Typical results are given in columns I and II of Table 1. It appeared that the teaching had reduced the number who considered energy to be a force but had increased the number who considered momentum to be a force. In other words we now had the label momentum attached to their concept of the physicists' momentum but children still had not distinguished clearly the differences between momentum and force nor clearly understood that momentum is not a force!

Of course some children had modified their views and their comments encouraged us to continue further with our approach. Joel was an 11 year old who changed his views from b-c-a to a-a-a (for questions 1-3 of Survey B) during the trial teaching sequence.

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[1] A copy of Survey B is provided in the Appendix. Survey A is a parallel form of this Survey (see Working Paper No. 34).

TABLE I: TYPICAL RESULTS OF THE TRIALS (References in Terms of Survey B - Appendix A)

Key: I - pre-teaching survey
II - post-teaching survey
III - post-post teaching survey
IV - post-teaching survey using a modified teaching schedule

		Form I (mixed ability)			Form III (average ability)			Form IV (upper ability)			Form IV (lower ability)		Form IV (top stream)
		I	II	III	I	II	III	I	II	III	I	IV	IV
Q.1,2,3	bca	11	19	5	16	18	1	15	20	1	24	12	3
	aaa	1	5	19	1	0	17	3	0	17	2	10	23
	aca	0	2	2	5	1	0	1	1	0	0	4	1
	baa	6	2	3	2	2	0	5	0	2	0	1	1
	acb	2	1	0	1	4	2	1	0	1	0	0	0
	aab	2	0	1	0	0	5	0	1	0	1	0	0
	other	12	4	4	4	2	0	1	0	0	1	1	3
Q.4	gravity + friction	1	9	18	1	8	19	3	3	18	1	6	14
	gravity + kick	9	4	3	11	8	4	9	3	0	11	8	7
	gravity	0	8	3	3	0	0	1	0	0	0	6	4
	friction + kick	7	4	0	1	5	0	0	0	1	4	0	3
	friction	0	3	3	1	0	0	0	0	0	0	2	0
	kick	11	2	3	11	2	0	3	6	0	9	3	1
	friction, gravity, kick	6	4	4	1	4	1	11	10	3	3	3	0
Q.5	zero total force	7	27	26	15	20	24	14	21	22	7	22	20
	downwards	16	4	6	9	6	1	13	1	0	11	3	6
	no force	11	3	2	5	1	1	0	0	0	10	3	3
Q.6	Yes, gravity	22	26	28	26	20	24	25	19	21	24	27	27
	no, not moving	12	8	6	3	7	2	2	3	1	4	1	2
Q.7	force	25	26	32	26	22	25	27	2	19	22	27	26
	no, force	9	6	2	3	5	1	0	20	3	6	1	3
Q.8	push	6	30	32	16	20	23	16	19	19	8	23	26
	pressure	17	8	6	16	11	0	12	1	1	23	11	0
	pull	8	28	31	11	19	23	15	19	19	6	24	27
	energy	14	0	0	8	7	0	9	2	2	12	3	0
	momentum	2	12	4	0	8	0	1	3	1	2	4	0
	motion	12	2	0	3	2	1	7	1	1	3	2	0
	push and pull (together)	1	4	16	1	8	23	10	14	17	0	16	26
Q.9	gravity	10	2	3	3	1	0	0	1	0	0	0	2
	friction	8	12	14	8	15	21	22	16	20	3	17	19
	stopped naturally	6	1	0	3	0	0	1	0	0	2	1	3
	ran out of force	7	17	4	15	11	4	4	3	2	23	10	5
Q.10	no total force	14	27	27	15	6	17	7	15	22	5	7	17
	total force	17	6	6	4	21	9	20	9	0	23	21	12

R. "What has Mr S. been talking about?"

J. "About force and momentum." ("Anything else?") "About how forces are related in different ways and how it is applied to objects."

R. "Pushes and pulls?" ("Yes.") "Okay, well here are three words ... FORCE - MOMENTUM - PUSH/PULL ... are we talking about different things or the same thing?"

J. "Well force, push and pull are pretty much exactly the same ... but momentum is not." ("How is it different?") "Well the momentum is how the object has speed but force is just what starts it off."

R. "Do you remember doing these questions for Mr S?" ("Yes.") "Can you remember what you put for the first three?"

J. "They are all (a) ... well because when the ball is on the way up ... the force on the ball is downward because of gravity, and once the ball has left the guys hand there is no more force on it except for gravity ... and when the ball if just at the top there is still gravity pulling it down ... which is why it has stopped ... and when it is on the way down there is of course, force pulling it downwards from gravity."

R. "Can you ... before he started teaching these things he had another set of questions similar to these ... I don't know if you can remember about that?"

J. "Yes ... I think I said that on the way up the force was upwards ... and then when it was at the top there was no force because it wasn't moving ... and when it was on the way down the force was pulling it downwards.

R. "So during the lessons you changed your mind about that?" ("Yes.") Can you really remember what it really was that Mr S. said that made you change your mind about that?"

J. "Well it was how he said that no matter what there is always gravity ... because gravity is always pulling down."

R. "And that is the thing that really sort of made you think about it?" ("Yes.") Right ... now we have got a real problem because what we are trying to do is to teach ideas about force and momentum and pushes and pulls and you seem to have got it pretty right in terms of what we were trying to teach ... but there is a lot of people in your class who even despite all that teaching by Mr S., chose (b)-(c)-(a) beforehand and still chose (b)-(c)-(a) afterwards ... in other words they didn't change their mind at all ... and that's a real problem ... we don't know how to get over that ... do you see how we might teach it to get other children to see it the same way that you see it?"

J. "Well we had limited teaching ... so if there was a longer period of time it might get through ... also I think if he demonstrated that there was always gravity pulling it down which is why it slowed and stopped on the way up ..."

R. "It is very important to you to have that idea?" ("Yes.") "When you say you had limited teaching ... what did you mean by that?"

T. "We only had four one-hour periods ... two were on momentum and two on pushes and pulls and force. He demonstrated on the last day about pushes and pulls and how there is gravity and if something is on the ground there is still gravity which holds it there ... if he took a little more time over it ... and really got it through ... and worked with each person individually ... and had a few more tests they would get it. I think."

R. "You don't think it is impossible to teach to 11 year olds?"

J. "No ... not at all.

Joel gave us the encouragement to continue our experiment!

FURTHER TRIALS

Faced with the disappointing post-survey results (columns II - Table I) a variety of approaches were adopted. With the Form 1 class an additional lesson was given. In this lesson a real effort was made to show the difference between momentum in a body and the force on a body. The results of this lesson appeared considerably significant as can be seen from the Form 1 results, column III - Table I. This post-post-survey was administered six weeks after the additional lesson.

With the Form 3 and Form 4 classes the results of the post-survey was discussed after the pupils had completed the survey and the correct scientific answer was discussed. With these classes the pupils were given an unannounced post-post-survey some four to five weeks later. The results of this final survey were quite dramatic (see Form 3 and 4, Column III results - Table I). A number of students were interviewed following this test. It certainly appeared that the pupils hadn't superficially learnt the right answer but now had a good understanding of momentum and force. The following is an extract from one interview where a pupil had explained that he had changed his ideas both during the teaching and during the discussion of the post-teaching survey.

I. "So some of the ideas you have always had, some of the ideas you changed during the teaching, and some of the ideas you changed when Mrs XXXXX went over the test?"

G. "Yes."

I. "And that was because Mrs XXXXX taught you when she went over the test or because you learnt some of the tricks in the questions?"

G. "Because I learnt some of the tricks in the questions."

I. "So you think if you did change your ideas it was during the teaching rather than just when she went over the test?"

G. "Well when she went over the test it meant that I had different ideas to the answers ... and that means that I knew that I had to change my ideas ... so I changed my ideas when I knew what was right ... when I was sure it was right."

I. "So the test made you aware of how your ideas were different to the right ideas ... but what ... you didn't know ... you weren't very clear ... exactly what the science idea was or exactly what your idea was?"

G. "I knew what she was talking about when she was teaching us ... but my ideas were slightly different.

This pupils final comment is a very profound statement. The advantage of feedback from well designed surveys and tests is obvious - such feedback leaves no room for ambiguity or misinterpretation.

Following the above work, a modified teaching strategy including a greater emphasis on the distinctions between momentum and force was developed. The results of the post-test following this teaching sequence (see column IV of Form 4 (low ability) results - Table I) gave some cause for optimism. Although these results are not dramatic, for example 57% choosing a-a-a after the teaching sequence, it must be noted that this was a lower band 4 form (top 40% of ability range absent). The results must also be compared favourably with the results given on p.5 of Working Paper No. 33, where only some 20% of sixth and seventh form physics chose a-a-a.

Further trials with some of the material, including classroom observations of children using the worksheets, led to the finalized Working Paper No. 34 - Teaching about Force. This document is not seen as an end point but, with the surveys included there, it is hoped that the activities provide a basis on which a worthwhile teaching sequence can be developed and subsequently improved further by individual teachers using their own post-survey results as a guide for further changes.

In addition to all this work one of the group (B.N.) tried an alternative approach with a top stream fourth form. This class used a ISCS individualised approach using the unit "Forces in Action". Many of the ideas on force and motion that we were interested in, were however not considered by this unit. The key ideas not included tended to be discussed formally with the whole class at appropriate stages during the series of lessons. From our visits to this classroom it appeared that the pupils had carried out many activities involving force in an informal self-paced environment which contrasted strongly with those few occasions when pupils were taught briefly in a formal situation about one or two key features of force and its relationship to motion. Unfortunately a pre-teaching survey was not given to the class, but the post-teaching survey showed promising results (final column of Table I). However it must be emphasized that this was a top stream class and that both the teacher and ourselves consider the approach used was only suitable for a class of such ability.

FURTHER COMMENT

The work carried out by the physics action group has a number of other interesting aspects associated with it.

As we were able to show from interviewing some of the Form 1 pupils a month after the sequence of work, some 11 year olds had dramatically changed their views about force and motion to ones which were scientifically sound. Undoubtedly many of these were the brighter pupils. However these are our future scientists and they are capable and ready to understand these ideas at that age.

One of us (B.S.) taught both the Form 1 mixed ability class and the Form 4 lower band ability class. In our view the Form 1 class were more eager to learn and to modify their views than the older students. One is left with the impression that children may ossify into their children's science view unless it is challenged when children are young. This is reinforced to some extent by the efforts of the other author (R.O.) to teach the ideas to first year University physics students. Despite considerable emphasis in lectures on this topic (naturally using a somewhat different approach to that proposed for Form I-IV) the post-survey results (see Appendix B for further details of the questions used) showed only a marginal change from a pre-test survey using Q.1-3 of Survey B (see Table II). Admittedly the post-post-survey (using question of Appendix B in the final examination) showed a much more substantive change. However this work suggests to us that it may not invariably be better to delay the teaching of an idea to a later age level just because it appears difficult.

Table II: Percentage Results of the First University Physics Students (N ≈ 140) on Q.1-3 of Survey B and Alternative Forms of this Question (See Appendix

	Pre-test	Post-test	Post-Post-test
a-a-a	45	49	87
b-c-a	42	25	5
a-c-a	10	9	4
a-c-b	-	9	1
b-a-a	1	8	3

If there is some substance in the above, then the problem is to find the age at which intellectual maturity is sufficient to appreciate the ideas but, on the other hand, the child has not become too fixed in his or her viewpoint. One is also of course left to ponder how appropriate it is for all children at any one particular age level to be exposed to the same learning experience.

It was also clear from some of our interview work that often children need time to think about an idea before they accept it as the way they will think about things. During two post-teaching interviews of 11 year olds, who still considered answers b-c-a were the best answers to questions 1-3 of Survey B (see Working Paper No. 34); the interviewer at the end of the interview (R.O.) put forward his view that because the pull of gravity was always acting, he preferred answer a-a-a. "Did they prefer a-a-a or b-c-a as the way they thought about it, now?" Both independently stated at that time that they preferred b-c-a. However in a class discussion some two weeks later both pupils were arguing vociferously for answers a-a-a, even though the interviewer was not present on that occasion.

Finally some will suggest that we shouldn't be trying to teach abstract concepts like force to 11 year olds. Perhaps so, yet Worksheet A (p.8 of Teaching about Force - Working Paper No. 34) can have a mixed ability class of 11 year olds <u>all</u> discussing in small groups whether forces are present or not in the particular situations shown. The abstractness of a particular concept is certainly of less importance if one has a definite concept attached to the label and it has applicability with respect to the instance being discussed. We believe intellectual discussion of this type is important so that children can challenge the views of others and have their own views challenged. Such is the best traditions of science and scientists.

We end with a quote from a fourth form teacher's comments about the trial unit.

R. "A lot of people would say that you know that girls are not as interested in, or as motivated in things like chemistry or physics as boys."

T. "Oh, I don't find that at all! Especially this last one we just did on force ... I couldn't get them off it ... I couldn't get them away from it ... we could have spent the rest of the year on it ... normally they are not too happy to sit and talk about things they like to do practical work and I like to encourage them to do practical work ... we didn't do very much practical work with that one ... yet they sort of sat and asked me questions day after day after day ... they had obviously done the thinking about it themselves and they would have gone on forever."

R. "So those activities ... did you do some of those pencil and paper kind of activities?" ("Yes.") "They in fact promoted the kind of discussion that ..."

T. "That was one case ... where ... I mean they had already done these things themselves like pushing people ... or on skateboards ... trying to pull someone along in a box and this sort of thing ... they know what would happen so that you didn't really have to demonstrate the thing over again ... oh, we did do some silly things like ... see if you could pull two of us together in a cardboard carton and this sort of thing but they had the ideas in their head and they were really keen to sort them out.

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APPENDIX A

LEARNING IN SCIENCE PROJECT

Force - Survey B

1 - 3. A netball player sends a ball straight up into the air just a small way. The questions are about the total force on the ball.

1. If the ball is on the way up, then the force on the ball is shown by which arrow?

(a)

(b)

(c)

2. If the ball is just at the top of its flight, then the force on the ball is shown by which arrow?

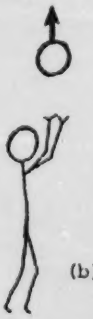
(a)

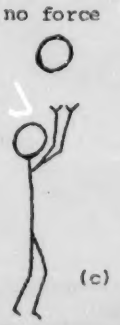
(b)

(c)

3. If the ball is on the way down, then the force on the ball is shown by which arrow?

(a)


(b)



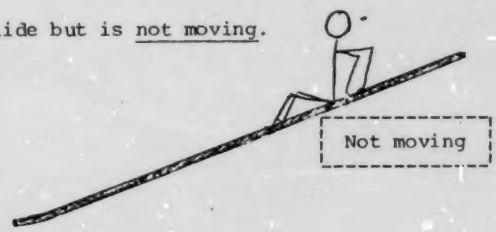
(c)

4. A soccer ball is kicked into the goal.

As it moves into the goal what are the forces on it?
(you can choose more than one)

(a) The force of the kick
(b) The force of gravity
(c) The force of friction

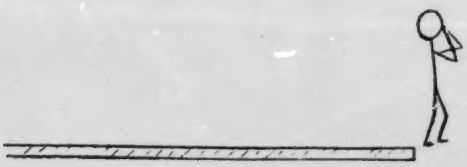
5. A person is on a slide but is <u>not moving</u>.



Which of the following is correct?

(a) There are many forces on the person but the total force is zero
(b) There are many forces on the person and the total force is downward
(c) There are no forces on the person at all

6. A diver steps off the end of a diving board very gently and slowly.



Just after she has stepped off, but <u>before she really started to drop down</u>, would there be a force on the diver?

(a) Yes, there is gravity
(b) No, she is not moving

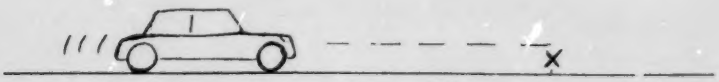
7. A person is leaning against a building. Is the person putting a force on the building?

   (a) Yes
   (b) No

8. Which of the following words give the best idea of force?
   (you can choose more than one)

   (a) motion (b) momentum (c) energy
   (d) pull (e) pressure (f) push

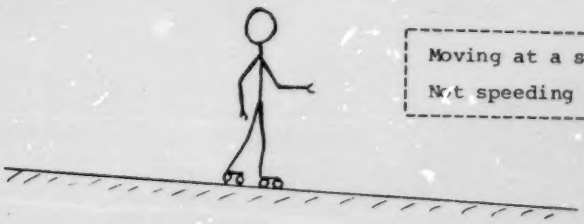
9. A car is travelling along a flat road when the engine stops going. The car slows down and stops at X.



   Which of the following could explain this? (choose one)

   (a) Gravity caused the car to stop
   (b) Friction caused the car to stop
   (c) The car just stopped naturally
   (d) The car ran out of force

10. A person on roller skates moves along a gently sloping path. The person is going at the same speed all the time. She is not getting faster or slower.



Moving at a steady rate.
Not speeding up or slowing down.

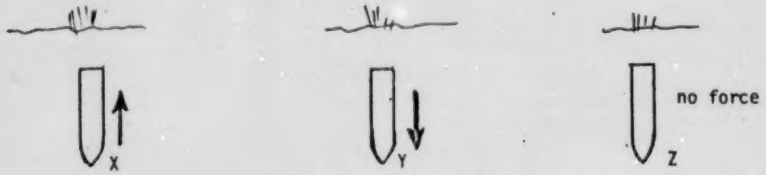
   Which of these sentences about the total force on the skater is correct?

   (a) There is no total force on the skater because her speed is steady
   (b) There must be a total force on the skater because she is moving

APPENDIX B - THE ALTERNATIVE FORMS OF Q.1-3 SURVEY B USED WITH THE UNIVERSITY PHYSICS STUDENTS

(a) The term test question which acted as a post-test where compared to Q.1-3 of Survey B. X is equivalent to a, Y to b, and 2 to c. Hence answer (c) (X-X-X) is the correct scientific response.

A used fuel tank from the SPACE SHUTTLE falls vertically into the sea. It travels vertically a small distance below the surface before re-emerging on the surface.
The following three diagrams represent possible directions of the total force on the tank.



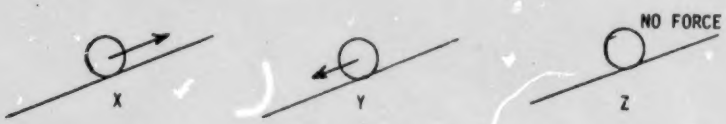
The <u>total force</u> on the tank i) just before it reaches maximum depth,
then ii) when it is at greatest depth,
then iii) when it is on the way up,

is best represented by the sequence;

(a) Y - Z - X
(b) X - Z - X
(c) X - X - X
(d) X - Z - Y
(e) Y - X - X

(b) A final examination question which acted as a post-post-test were compared to Q.1-3 of Survey B. X is equivalent to b, Y to a, and Z to c. Hence answer c (Y-Y-Y) is the correct scientific response.

A tennis ball rolls up a small incline, comes to rest, and then rolls down again. The following three diagrams represent possible directions of the <u>total force</u> on the ball.



The total force on the ball i) just before it reaches maximum height
then ii) when at the greatest height
then iii) when it is on the way down

is best represented by the sequence;

(a) X - Z - Y
(b) Y - Z - Y
(c) Y - Y - Y
(d) Y - Z - X
(e) X - Y - Y

LEARNING IN SCIENCE PROJECT

TOWARD SOLUTIONS:

The work of the

Chemistry Action-Reseach Group

University of Waikato
Hamilton, N.Z.

WORKING PAPER No. 35

LEARNING IN SCIENCE PROJECT

The Chemistry Action-Research Group (1981-1982)

Sandie Ball (1981)	Hillcrest High School, Hamilton.
Peter Biggs (1982)	Auckland Grammar School.
Triscia Briscoe (1981)	Rotorua Boys' High School.
Alison Cosgrove (1981)	Melville High School, Hamilton.
Mark Cosgrove	Hamilton Teachers' College.
Keith Dalton (1981)	Peachgrove Intermediate, Hamilton.
Paul Furneux (1981)	Otumoetai College, Tauranga.
John Lambert	Tokoroa High School.
Terry Meldrum (1981)	Fairfield College, Hamilton.
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THE WORK OF THE CHEMISTRY ACTION-RESEARCH GROUP

Roger Osborne, Brendan Schollum and Sue Russell

INTRODUCTION

In the action-research phase of the Learning in Science Project four groups of people worked on problems identified in the in-depth phase of the Project. The Chemistry Action-Research Group considered problems related to the teaching and learning of ideas associated with particles and changes; problems which had been earlier identified in the three working papers , Particles (No.18), Physical Change (No.26) and Chemical Change (No.27).

The group was chosen to provide a variety of experiences in teaching and a range of academic backgrounds in chemistry. It consisted of practising classroom teachers including Learning in Science Project team members. Prior to the first meeting of the group in June 1981 individual team members were sent the three working papers of the in-depth phase - Particles, Chemical Change, and Physical Change - and asked to consider whether the problem and difficulties described in these papers related to real, important and solvable issues.

THE FIRST MEETING

There was a wide ranging discussion of the problems involved in teaching chemistry at the 1-4 level. The discussion emerged from points which had been both explicitly and implicitly raised by the working papers.

Of major concern was the place of the particle model in junior chemistry teaching. Questions raised included;

i) Should or can a particle model of the states of matter be taught?

ii) If so, what aspects of a particle model should or can be taught to whom?

These questions seem to be ones that groups of chemistry teachers everywhere have difficulty resolving and hence it is not surprising that the action-research group had some difficulty attempting to resolve these points also.

Nevertheless, it was agreed that;

a) Chemistry is, and should be, the study of things changing into other things. To this end we need to encourage children to identify groups of similar changes, e.g. various things evaporating, various things burning, and things melting or dissolving (including their differences).

b) Children have ideas about how and why particular events do occur, but these ideas are frequently quite different from the scientific viewpoint. From this perspective teaching chemistry needs to be seen as a reshaping, or modifying of children's ideas rather than transmitting new knowledge to blank minds.

c) A particle model should be introduced only as and when it is necessary to help children make sense of new experiences and where it will help them to replace their views about certain changes with a more intelligible, plausible and useful viewpoint. However, it is essential that it is the child who considers the new viewpoint as more intelligible, plausible and useful and not the teacher! The particle model should arise from a perceived need by the pupils.

d) So that new ideas about changes are linked to, build on and modify old ideas it is important that many of the changes that are considered are familiar changes, e.g. found in the home. It is necessary to break down the view that "science is something done to us by strange people (science teachers) in strange rooms (science laboratories) using strange materials (equipment and uncommon chemicals)".

e) Many activities have to be used to establish concepts such as "dissolving" and "burning". Many illustrations are required.

f) It would be desirable that activities used to modify children's ideas related to contexts where a knowledge of children's ideas is already known, viz. contexts used in the in-depth phase interviews, e.g. rusting, burning of a candle, boiling of water.

g) One of the key ideas which children need to really appreciate is that when changes occur matter is neither created nor destroyed.

THE FOLLOWING MEETINGS

The group met again on three occasions, in August, October and November. Before the August meeting many of the group had surveyed pupils with trial survey material which, in modified form, can now be found in the units produced by the group. Also, various members of the group had explored in an ad-hoc way teaching strategies, some original, and some borrowed from other sources which may have resolved some of the issues discussed at the first meeting. At each of the meetings these strategies were discussed so that further trialling, refining, and evaluation could occur.

a) Two group members (T.B. and J.N.) discovered and used a chapter "A candle burning" from Integrated Science Book 2, Wreake Valley Project. This unit was considered potentially useful, in terms of helping children learn more about a familiar set of changes and confronting some of the ideas children hold about burning. Initial trials with the material and evaluation of the burning that had occurred suggested the unit could be adapted to provide a useful unit of work.

b) Three members (P.S., A.C. and T.M.) investigated problems related to the particle model. Survey questions which investigated by pictorial representations of children's ideas of the particle nature of matter were developed. Situations and activities which might help pupils develop a particular model were investigated tentatively.

c) Three other members (R.T., K.D. and S.B.) explored children's skills of observation and use of the other senses in the context of dissolving. Children's ideas about what was happening when something dissolves were brought into the open and these ideas explored by activities and discussion.

d) Three members (P.F., A.C. and T.M.) considered children's views about the boiling and condensing of water and how these ideas might be modified by activities and discussion.

Group members further considered the role of the particle model in chemistry teaching and considered the desirability or otherwise of attempting to distinguish between chemical and physical changes at the Form 1-4 level. The view that the particle model should be introduced as and when it was appropriate to help children make sense of their experiences was reiterated. The distinction between physical and chemical changes was considered to be not entirely helpful or useful even to chemists.

As a result of the work done by the group between these meetings, and in the light of further discussion it was agreed to work toward producing units for teachers. As a theme for the units it was decided to consider the various changes that occur when familiar things are heated or mixed together. Three units were planned and it was decided that each unit would contain:

i) Information on children's ideas related to the phenomena to be considered in the unit.

ii) Information on the scientists' ideas related to the phenomena to be considered in the unit.

iii) A survey to help teachers clarify their own views and to establish the views of pupils in their classrooms.

iv) Suggested teaching activities designed to modify children's views in a way which would help children make more sense of their world.

THE THREE UNITS

On the above outline the three units developed were;

a) Working Paper No. 36: Burning

This unit focuses on the burning of a candle. The rationale here is that a great deal can be found out about one particular type of chemical reaction using this everyday phenomena. This enables pupils to link such understandings to their view of the world.

b) Working Paper No. 37: Reactions

The unit focuses on a range of phenomena, each of which involves a chemical reaction. Also considered are substances being mixed which do not result in chemical reactions so that a comparison can be made. Again

the overriding concern is to try to use everyday phenomena as far as is possible so that children can modify their own intuitive ideas rather than learn chemistry as something which does not relate to their world. Several familiar reactions, e.g. rusting are looked at in greater detail.

As well, what happens when substances dissolve is clarified. Emphasis is centred on the idea that at this level these need not be considered as chemical reactions.

c) Working Paper No. 38: Heating and Cooling

This unit begins by considering what happens when things are heated. Three types of changes are identified.

i) the change is not obvious, temporary, and easily reversed, e.g. the heating of iron causing expansion.

ii) the change is obvious, temporary, and easily reversed, e.g. the forming of ice.

iii) the change is obvious, seems permanent, and is very difficult to reverse, e.g. the heating of sugar, the burning of a candle.

This working paper considers i) and ii) only. A simple particle model is introduced during the unit as a useful explanation for things that have been observed to happen. Further evidence for particle motion is then discussed. Changes of type iii) are considered in the other units (see above).

TRIALS OF THE MATERIALS

At this stage (September 1982) the material produced by the Chemistry Action Research Group is still under testing and further development. Nevertheless the following two sets of results, one for the Burning unit and the other for the Heating and Cooling unit, give an indication of the

type of results being obtained and their implications for further work.

Burning: The results provided here give details of the trialling carried out in one school during 1982 on Working Paper No. 36.

The Unit was taught as presented in the paper to three 3rd form classes in a girls' school by three different teachers. Two of these teachers were reasonably familiar with the Learning in Science Project material while the third teacher was given a brief introduction to LISP. Pupils in the three classes were surveyed using the survey in the Unit (see Appendix A) before, shortly after and three months later (no revision). The results presented below are from some 60 Form 3 pupils taught by the two teachers familiar with LISP. The classes were above average classes with TOSCA medians of 92% and 76%. The results of the third class are not included although they largely reinforced the trends which follow for the two classes whose results are provided.

Question 1: The results for question 1 are provided in Figure 1. It is interesting to note that with these more able pupils 70% of them already held the scientific view prior to teaching. This percentage is significantly lower when the full ability range of a typical school is considered. The continued tendency toward a more scientific perspective during the three months following teaching only involves a few children. However it is a tendency that has occurred elsewhere (see LISP Working Paper No. 32 - The Work of the Physics Action Research Group).

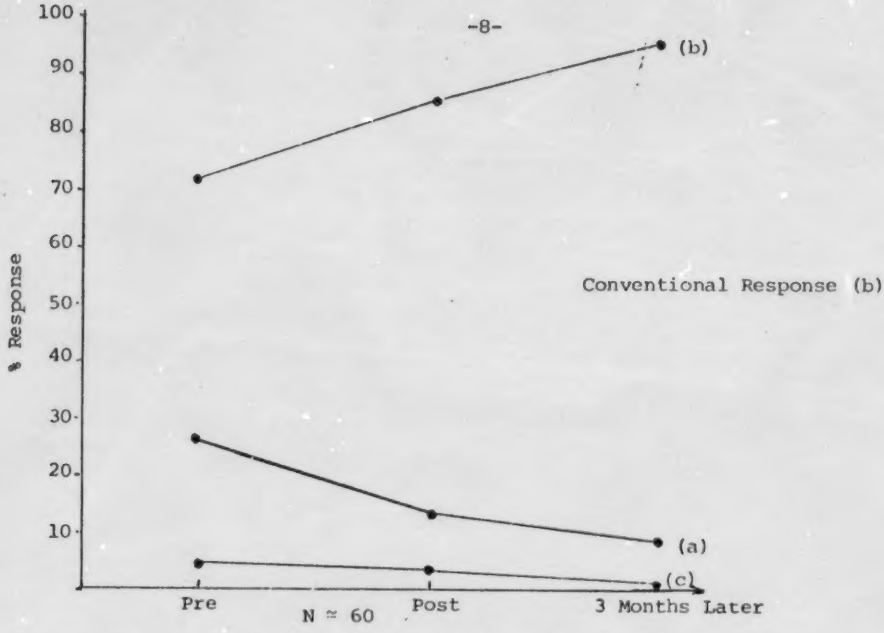


Figure 1: The Results for Question 1

Question 2: Only 2% of the pupils in the pre-survey considered the wax had any chemical function. The post-test results (see Figure 2) show a dramatic change. However it is rather interesting that a slight shift occurred during the following three months!

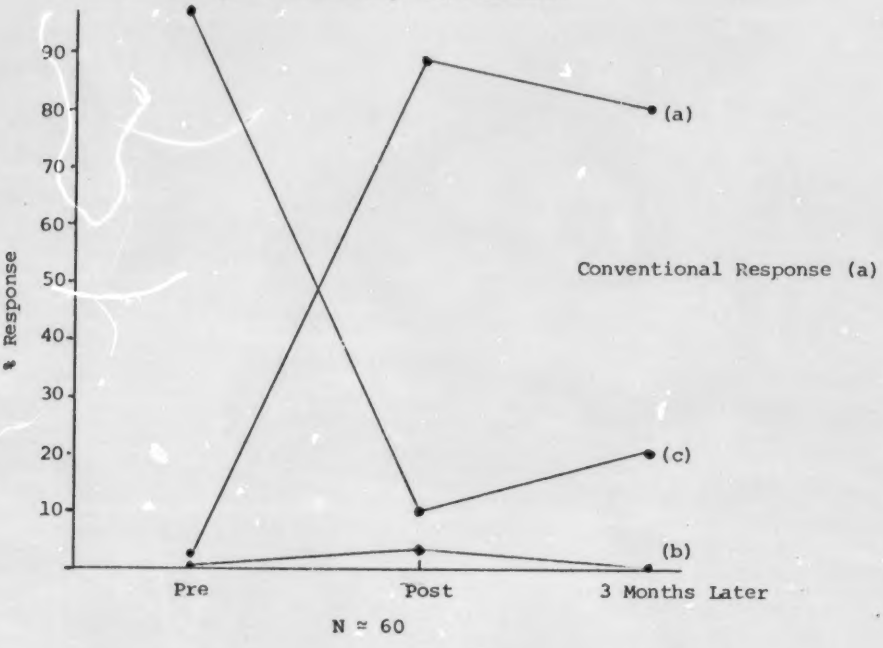


Figure 2: The Results for Question 2

Question 3: Again the results (see Figure 3) showed some dramatic changes. However this is a specific result observed by pupils during the teaching sequence. 1 gram loss occurred in 10 minutes. This was detected by pupils using an electronic balance because the teacher had failed to obtain any observable change when trialling the activity at home using kitchen scales. Despite direct observation it is interesting that one pupil considered it was more after 3 months reflection!

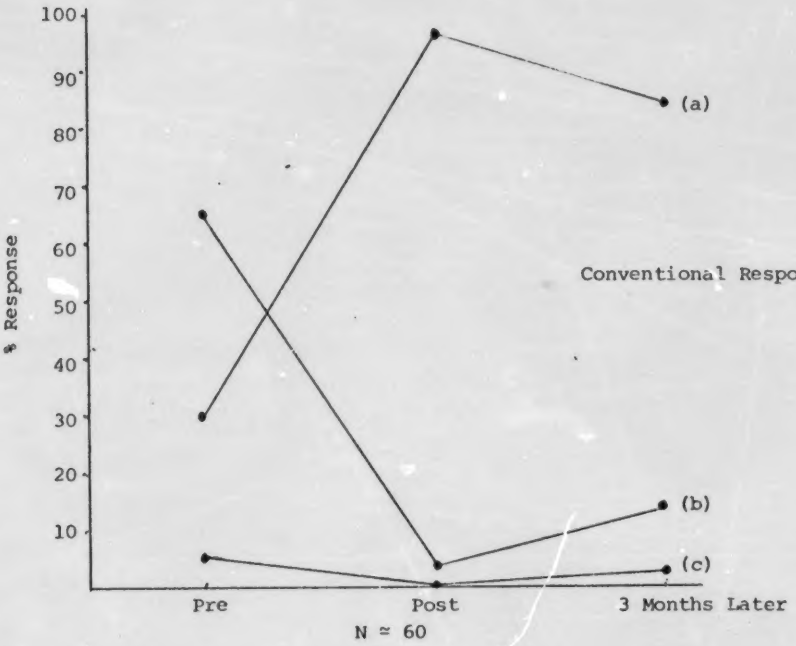


Figure 3: The Results for Question 3

Question 4: Burners were not specifically taught in this unit, so that the shift in viewpoints shown in Figure 4 is possibly more significant than in Question 3.

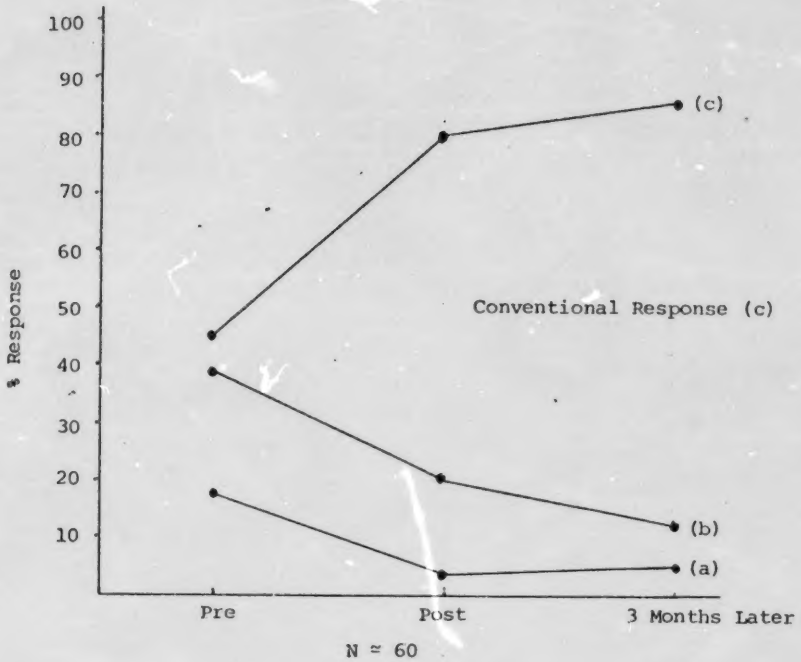


Figure 4: The Results for Question 4

In conclusion it would appear from these results that as far as ideas about candles and burners are concerned the Unit, as taught by these teachers produced a marked shift in pupils' views towards the conventional viewpoint. The results give some cause for optimism.

Heating and Cooling: The paper entitled Heating and Cooling was trialled and then modified to a form which was more widely circulated in 1982. While it is hoped that there will continue to be modifications in the Unit with time, it is useful to consider how successful the present Unit is in modifying children's ideas. The results in Table I are the combined results from four classes. The post-test results were obtained one month after teaching. The questions can be found in Appendix B.

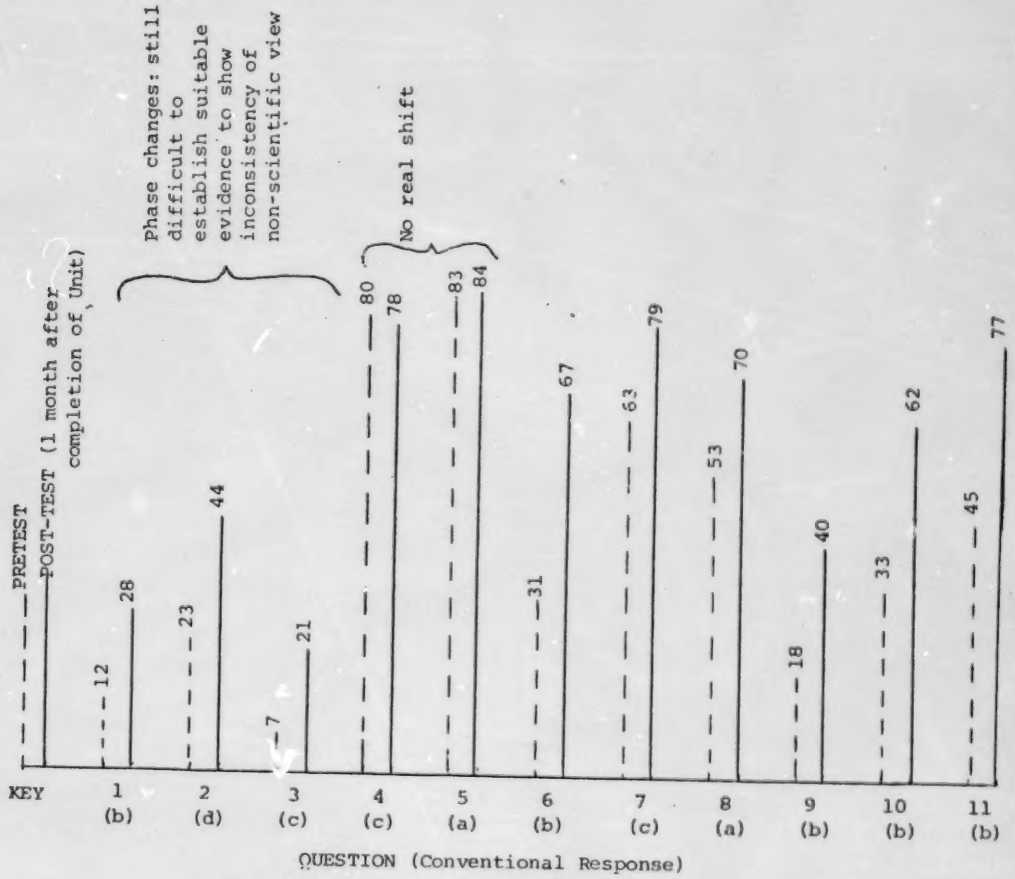


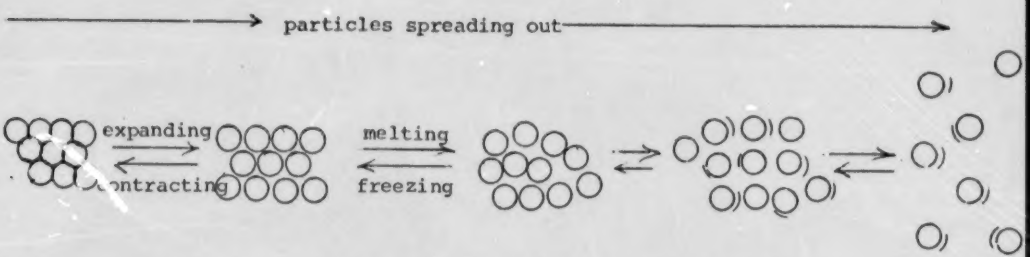
TABLE 1: Percentage conventional response of Form 3 Pupils (N = 105, 4 classes). See Appendix B for questions.

The results indicate only a marginal shift with respect to the phase changes (Q.1-4). It is considered by teachers who have tried the Unit that it is difficult to establish suitable evidence to show the inconsistency of non-scientific views. In particular, despite considerable class discussion, pupils were not convinced that evaporation of water does not involve the splitting up of water into constituent atoms (the gases oxygen and hydrogen).

There appeared to be little change with respect to Q.4 and 5. The Unit does not relate directly to these ideas and little transfer of ideas seems to have occurred. More significant changes would appear to have occurred with respect to Q.6-11.

Teachers who have taught the Unit find that children are attracted to participating in discussion when they realize the teacher was truly interested in their views and in asking why individual people held particular views. Pupils participated in the practical work/discussion because, in our view, the overview of the Unit was clear particularly after the first two activities.

One teacher at least considers that the Unit could be improved by pupils considering and discussing the following diagram.



It was also felt by some that less emphasis is required on attainment of model before the wider range of experiences is provided for pupils.

In summary it would appear that a number of improvements could be made to the Unit. However it is undoubtedly difficult to genuinely change children's ideas related to some of these phenomena (see for example Nussbaum and Novick, 1982).

CONCLUSIONS

Undoubtedly the Chemistry topics gave the Learning in Science Project team some considerable difficulty. The nature of chemistry at the school level is under considerable debate at present (see Osborne, Cosgrove and Schollum, 1982). While the results of the in-depth phase perhaps added fuel to the debate it did little to really clarify in our own minds what school chemistry should be about.

Nevertheless a stance was taken (p.2 and p.3) and the action-research phase work was begun. Undoubtedly those involved in the research were motivated by the findings of the in-depth phase as they related to Chemistry. Furthermofe the group appeared to gain professional satisfaction from the work as they tried to resolve some of the problems identified; given constraints of class size, time, and equipment.

As teaching material was developed further teachers were involved in the trials of the material. In our view:

i) Teachers responded positively to the introduction of surveys which were developed to illustrate the nature, and the extent, of the views held by pupils in their classes. This information was particularly useful before teaching a Unit.

ii) Teachers were not only varying the content being taught; the teachers behaved differently. This was demonstrated within their classes, where more time was spent in determining and clarifying the views held by pupils using the survey material and generating discussion within the class. Also feedback from pupils has been positive because the activities which were planned for and carried out following initial discussion sought to reinforce or change the views held, and hence the pupils appreciated the purpose of these activities.

iii) Teachers who trialled the Units felt that information about how and what views had changed as a result of their teaching was extremely worthwhile.

We hope that teachers who worked in the action-research group, who were involved in trialling the Units, or who simply use and improve the Units which have been produced, will continue to rethink and try to improve particular strategies to modify children's ideas. In the final analysis this is the real measure upon which the success or otherwise of the Project should be judged.

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APPENDIX A: A SURVEY OF SOME IDEAS OF BURNING

1. When a candle is alight,

   (a) air is needed to help the flame, but none of it is used up.

   (b) part of the air changes into something else.

   (c) air is not needed when a candle burns.

2. Consider what some people say about the wax when a candle burns. In your view, which is the best statement about the wax?

   (a) The wax is burned up in the candle flame.

   (b) The wax is not burned up; it holds up the wick as the wick burns.

   (c) The wax is not burned up; it melts and stops the wick from burning too fast.

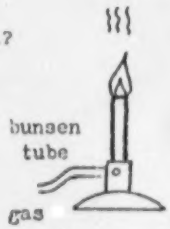
3. A candle is put on the pan of some kitchen scales, and lit. After 60 minutes the reading on the scale would be;

   (a) less

   (b) the same

   (c) more

4. Just above the flame it is hot. What is it that is hot?

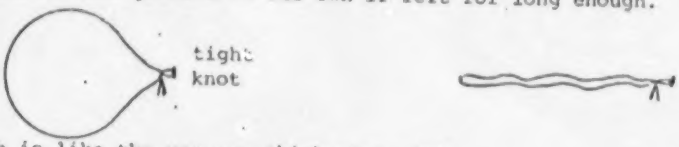


   (a) The air only.

   (b) The air and the same gas as that in the bunsen tube.

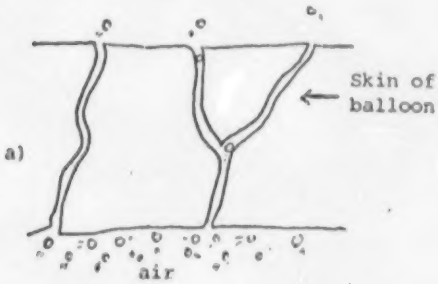
   (c) The air and at least one gas that is different from that in the tube.

A balloon will go down on its own if left for long enough.

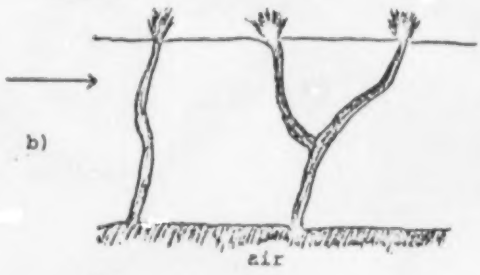


Which is like the way you think about it?

air particles escape through very tiny holes in the balloon.



air squeezes out like toothpaste through very tiny holes in the balloon.



We smell the scent from flowers easily. Which diagram is most like the way you think about how this happens?

a)

particles from the flower spread through the room and the nose detects these particles.

b)

the scent streams out but no particles leave the flower.

The following questions are about familiar substances which are solids, liquids or gases.

When a thermometer is put in hot water, the liquid of the thermometer (often mercury) rises up the tube. The reason for this in your view is:-

(a) the liquid is made up of particles which get bigger as the liquid is heated.

(b) the liquid is made up of particles which move round more and spread out.

(c) the liquid is <u>not</u> made up of particles.

One way to show air in a bottle is like this.

A boy tries to suck all the air out of the bottle, and he manages to suck half the air out

After half the air is sucked out, he sticks his finger over the end to stop any air getting back in. Which diagram best shows how you would picture the air left in the bottle?

(a)

(b)

(c)

(d)

Which do you think is the best reason that the particles of the air in the flask do not fall to the bottom of a flask?

(a) The particles are always moving about.

(b) The particles are packed in so tightly that they are unable to fall.

(c) Air keeps the particles from falling.

(d) The particles are so small gravity does not affect them.

In a flask containing air, what is there between the particles?

(a) Air

(b) Nothing at all

(c) Gas

(d) Oxygen

9. A balloon is put over a bottle that contains nothing but air. The air is shown by the dots.

When this bottle is placed in hot water the balloon fills out.

Which of these diagrams do you think best shows what happened to the air?

(a)

(b)

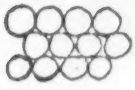
(c)

(d)

If we heat a solid we find it grows slightly bigger (if it doesn't melt!)
One way we could picture the finest detail of the solid is shown:

Solid particles

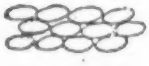
Which shows best what you think happens when the solid is heated and gets bigger.

(a) 

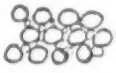
the particles grow in size

(b)

the particles move round more

(c) 

the particles stretch out

(d) 

more particles are made by the heat

LEARNING IN SCIENCE PROJECT

TOWARD SOLUTIONS:

The work of the

Activities Action - Research Group

University of Waikato
Hamilton, N.Z.

WORKING PAPER 46

Working Paper No. 46 is the first in a series of papers on Science Activities. Others in the series are:

Working Paper No. 47	-	Science Activities: The Problem
Working Paper No. 48	-	Science Activities: Specific Problems - some solutions
Working Paper No. 49	-	Science Activities: wider considerations

THE WORK OF THE ACTIVITIES ACTION-RESEARCH GROUP

John Lambert and Ross Tasker

December 1981

INTRODUCTION

The Science Activities Action Research Group (S.A.G.) considered problems related to the use of science activities in teaching and learning of science ideas, problems which had earlier been identified and described in working papers of the exploratory and in-depth phases of the Learning in Science Project.[1]

The personnel to make up the group were chosen to provide a variety of experience in, and perspectives of, the use of science activities in teaching as well as a range of academic backgrounds in science. It consisted of practising classroom teachers and Learning in Science Project team members. (See Appendix 1).

Prior to the first meeting in March, 1981, individuals were sent the working papers of the in-depth phase - Focus on Experiments and Focus on Process Skills and asked to consider whether the problems and difficulties described in these papers related to real, important, and possibly solvable issues.

THE MEETINGS OF THE GROUP (March 10, 1981)

The First Meeting

The group agreed that the problems identified and described by the papers appeared real and were wide spread. No attempt was made at this time to direct discussion other than to the points of the papers being considered. As a consequence, reaction to the problems described was diverse and reflected the differences in teaching approach represented in the group. Not surprisingly there was a wide range of opinion as to

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1. Working papers - Focus on Experiments (No.2) Focus on Process Skills (No.7) Visits to a classroom No.1 to No.4 (Nos.13, 39, 40, 41) and Children's Views and Classroom Experiences (No.43).

how the problems might be resolved. However, general agreement was reached that the group should aim to produce material for in-service training work with teachers that attempted to deal with the problems described in the papers. To that end members of the group agreed to undertake specific tasks and report on them at the second meeting. These tasks were:

i. To investigate the wording of instructions in science activities in an attempt to enhance the likelihood that children will do what is expected.

ii. To look at the planning involved in a science activity to see if the impact and effectiveness of the activity can be improved.

iii. To consider ways of highlighting and assessing aspects of science activity work often overlooked or ignored e.g. expected skill level of pupils.

The Second Meeting (April 28, 1981)

The responses to the working briefs accepted at the first meeting reflected the diversity of views apparent in that meeting. Some of the material was presented in considerable detail but the convenors of the group were confronted with a difficulty in that the specific problems outlined in the working papers, mentioned earlier, had not been dealt with. The problem essentially was to direct the enthusiasm of individuals and the group to deal with the specific problems of the working papers and yet use the material already produced which represented a great deal of thought, hard work and experiences.

The Third Meeting (July 29, 1981)

Prior to the third meeting, JL and RT spend some time considering ways and means of dealing with the problem outlined above. It was decided that RT would spend some time outlining the LISP project team members view of science activity concerns. The discussion point outline (see Table 1) proved to be a very provocative, and a good deal of animated discussion ensued.

TABLE 1 Crisis points in a science activity +

The teacher's proposed problem for pupils to investigate	needs to become →	The pupil's own problem
The teacher's proposed activity for pupils to carry out	needs to become →	The pupil's own activity
The teachers solution of the problem	needs to be → related to	The pupil's solution

+ An activity where a scientific problem has to be solved

RT also produced a table (TABLE 2) which allowed members of the group to focus on specific issues..

As a result of this discussion more specific working briefs were accepted by some members..

TABLE 2 : Problems that can occur in science lessons

	Some possible mismatches between teacher and pupil preceptions. It would be extremely rare for all these to occur in any one lesson		Some consequences of the mismatch (if it does occur).
Relating to setting the scene of the lesson	Teacher's Viewpoint	Pupil's Viewpoint	
a. Scientific context of the lesson/activity	The lesson/activity is seen as part of a related series of experiences	The lesson/activity is seen as an isolated event.	Pupils do not consider the lesson/activity against important prior experiences.
b. Scientific purpose of the lesson/activity	The scientific purpose of the lesson/activity is specific and obvious.	The purpose of the lesson/activity is not obvious.	Pupils guess at and invent what seems to them to be a reasonable purpose.
c. Scientific design of the investigatory activity	The activity has certain critical scientific features which enable particular ideas to be tested.	The critical scientific features of the activity are not recognised or understood.	Pupils are unaware of which aspects of the activity need particular attention and why.
Relating to pupils			
a. Doing the activity	What the pupils are to do is obvious and requires skills the pupils possess.	What to do is not understood and the skills needed are not available.	Pupils do things which they think appropriate to reach the end of the activity.
b. Getting results	Pupils know what to look for and will recognise the result of the activity.	What to look for and how important a result is, is not clear.	Pupils focus on, and observe, unexpected aspects of the activity. They are preoccupied with "What is supposed to happen?"
c. Thinking about what was done and what happened	Pupils will consider critically their actions and findings.	There is no awareness that actions and findings should be critically examined.	Pupils see the activity as 'getting the right answer' or guessing what the teacher wanted from the activity.
Relating to outcomes achieved			
a. Evaluation of the experience	Pupils will consider the experience against the ideas and perceptions of scientists' science.	The experience if considered against ideas and perceptions of childrens' science.	Pupils have difficulty relating what they did and saw happening to their thinking.
b. Significance of the experience	There are pre-determined outcomes which are significant for achieving the teachers aim.	The significant outcomes are not detected or detectable because they do not relate to the personal view held.	Pupils develop negative attitudes to school science as being not relevant.

The Fourth Meeting (September 22, 1981)

At this meeting it was evident that a good deal of in-class work had been completed by members of the group. This work had two aspects:

i. Work that had been initiated by group members in response to the discussion in meeting three. This work involved language investigation, teacher strategies and further work with teacher and pupil aimed survey material.

ii. RT developed a science survey with evaluation notes based on a science experiment taken from a widely used textbook. Members of the group had worked this activity with a range of classes obtaining 'in context' feedback of the problem points outlined in RT table (Diagram 2).

The Fifth Meeting (November 11, 1981)

This session was a finishing off session; the main point of concern being the way that material with broad terms of reference could be developed into a useful package. The decision arrived at was that the material would be organised into three units. The units to be as follows:

Working Paper No. 47 Science Activities : The Problem

This unit would set out the problems as identified by LISP and provide teachers with activities which would help them see the problems in their own context.

Working Paper No. 48 Science Activities : Specific Problems - Some Solutions

This unit would state those problems the action-research members had sought to respond to, describe the nature of those responses and their impact on the learner and teacher.

Working Paper No. 49 - Science Activities - Wider Considerations

This unit would explore the role of science activities in the teaching and learning of science and attempt to relate science activities to a range of teaching approaches.

THE WORK OF THE GROUP

1. The Planning of Science Activities

A number of members of the group worked in this area of concern (J.G., B.W., J.L., G.D and D.W.). The original contentions were:

(a) That teachers are often so concerned about the equipment and material problems associated with activity work that they give little thought to the activity itself. Why the activity is part of the programme and what they hope the pupils to achieve in the course of the activity are not considered.

(b) That teachers have a very narrow view of what constitutes a science activity - that is a view restricted to practical work in a laboratory.

In one avenue of research a series of checklists for use with science activities were developed, trialled and modified a number of times in the course of the year. These were trialled in the schools of the developers as well as at in-service day courses in the region.

In their final form these checklists became:

1. An index card for Planning Science Activities
2. A checklist for Planning Science Activities
3. A checklist to Evaluate a Science Activity
4. A checklist for Pupil Evaluation of a Science Activity

The other main research avenue involved broader planning issues. Here work involved the drawing together of ideas gained from the personal experience of group members in setting up programmes of work from scratch, and the findings of the Learning in Science Project. This work was to provide the material for Working Paper 49, Science Activities - wider considerations.

2. Teaching Strategies and Science Activities

A number of enquiries centred on the language used in the instructions to science activities were carried out by group members (C.J. and B.W.). Work was carried out on

- problems caused by instructional words
- problems caused by the form of instructions
- the use of focus questions in the instructional material
- exercises in scrambling and unscrambling instructions
- the use of support diagrams
- the use of centre of interest techniques

Some of these enquiries were completed to a stage where they could usefully be written up, in Working Paper 48.

A number of enquiries (R.T., J.P., B.W., C.J.) focused on the form of assistance which can be made available to pupils with specific learning difficulties related to science activities. The use of survey material to identify pupils with these problems provoked much interest and continued work in this area is anticipated. The influence of such surveys in deciding the appropriateness of an activity, as carried out in a lesson, is potentially a very useful teaching device.

3. Assessment and Science Activities

The development and use of checklist and profile recording/reporting techniques for those aspects of activity work which teachers acknowledge as being important, but ignore in their assessment procedures was the concern of one group member (L.W.). This area of concern needs some intensive work especially in the area of:

1. How specific skills can be tested.
2. Establishing skill and attitude inventories for individual pupils.
3. Profile recording and reporting.

CONCLUDING COMMENT

The co-ordinators of the group (RT, JL) were concerned to obtain an original response to the Learning in Science Project findings related to Science Activities.

Consequently at the initial meeting there was no direction given to members as to the way they might respond through their teaching to the findings. However, it was hoped that a number of specific problems associated with Science activities had been recognised and accepted. This was not the case, for at the second meeting when initial responses to the finding were tabled a number of unexpected perspectives were apparent.

Looking back on the material and discussion of meeting one, two possible reasons for this position seem likely. (i) The L.I.S.P. papers focusing on Process Skills and Experiments did not spell out the specific problems in science activities in a way that teachers immediately recognised and/or (ii) While a general problem in science activities was accepted, the specific problems identified by L.I.S.P. were not.

This issue was clarified by the co-ordinators, prior to meeting 3, involving group members with an evaluation survey based on a science activity, and introducing further L.I.S.P. material in meeting 3 - from Working Paper 43 - Children's Views and Classroom Experiences (see Table 2).

The above strategies enabled the co-ordinators to refocus the developments that individuals had initiated without dampening what was obviously a real desire to enhance science activities as a teaching and learning vehicle.

The stronger direction given by the co-ordinators at meeting 3 did bring about a closer link between the L.I.S.P. work and the action research.

The above redirection was not achieved without considerable debate. Some group members were concerned that they were being asked to abandon a philosophy of teaching science which had been formed from considerable experience and thinking. This debate forced everyone concerned to think carefully through the significance of the L.I.S.P. findings in terms of their own teaching. By the time Working Paper 49 had been drafted a common position based on the view that successful science teaching required active teaching using a variety of approaches was reached.

Although at times this debate appeared to cloud what the co-ordinators saw as the issues of central concern, in retrospect the debate was undoubtedly the thing which clarified the L.I.S.P. philosophy for the members of this group.

APPENDIX 1

The Science Activities group comprised:

Grant Duane	-	Western Heights High School
Tony Friedlander	-	Putaruru High Shool
John Grant	-	Tokoroa High School
Colin Jackson	-	Tauponui-a-Tia College
John Lambert	-	Tokoroa High School
John Provo	-	Tongariro College
Brendan Schollum	-	Learning in Science Project
Ross Tasker	-	Learning in Science Project
Leigh Webber	-	Kawerau College
Dave Whaley	-	Rotorua Boys High School
Tim Willetts	-	Tokoroa High School
Brian Woolhouse	-	Tokoroa High School